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ERRATUM.

Page 1, heading, *for* "Capt. Cooke, R.E.," *read* "Capt. Cooke, 22nd Regt."

THE

DEVELOPMENT OF FIELD ARTILLERY.

Précis of the work "Development of the Matériel, Organisation, and Tactics of Field Artillery, from 1815 *to* 1870."

BY

CAPTAIN COOKE, R.E.,

TOPOGRAPHICAL DEPARTMENT.

[COMMUNICATED BY THE DIRECTOR OF ARTILLERY.]

Every person who is in any way conversant with the principal features which characterised the field artillery at the commencement and close of the period referred to, and the treatment of which is attempted in the present work, will appreciate the extent, importance, and difficulties attending the solution of the task. The transition from the system of smooth-bore to rifled guns may be regarded more especially as one of the most interesting, important, and instructive periods in the development of field artillery. It must by no means be imagined that this development has reached its climax, or that a stop should be given to its progress.

The present stage, however, appears to be particularly suited to the casting of a retrospective glance. During the period which has elapsed since the general introduction of rifled guns, the system has been tested in two great wars, and its strong as well as weak points have become well known. We are therefore thoroughly able to decide where improvement is needed, where improvement is possible, and how far the perfecting of the system is practicable.

The author, from whose work the following pages are taken, subdivides his comprehensive *matériel* into five periods, which we will here deal with *seriatim,* according as they are more or less closely connected with the present.

Period I. Development.—From 1815 to 1850.

The close of that period of warfare which culminated at Waterloo marked an era at which it was universally admitted to be necessary to provide for the acknowledged deficiencies (short-comings) in the *matériel* of the period passed through. The Austrian system of field artillery was, however, so deeply rooted, that it still remained much on the same basis as in 1753, when established by Prince Lichtenstein. It was not till after the successive

progress made in the artilleries of other nations, and the increased effect obtained from rifled small-arms, at length compelled a change, that the then Colonel Br. Smola, jointly with Major Plöchinger, received an order in 1850 to frame a project for a new system of field artillery. From this starting point, the so-called "*projects-matériel*" (experimental material), with a system of gun-carriages and wagons of materially lighter construction, became gradually developed, and was eventually introduced on the adoption of rifled ordnance.

Even as early as this period, it was the primary aim of the artilleries of all nations to adapt the construction of the *matériel* to the tactical requirements; the principle that the gun was no longer to be regarded as a simple wagon but a decisive instrument of warfare, became more and more determinedly asserted. The field artillery ammunition consisted of solid shot and case for the gun, common shell and case for the howitzer. Shrapnel was added in the second part of this period. The solid shot was the principal missile of the field gun. The shell was fitted with the simple wooden fuze, and did not as a rule burst over the point aimed at, but generally behind it. The accuracy of the shell practice was proverbially very bad. No improvement took place until the introduction of the "eccentric" shell. The shrapnel was also originally fitted with the wood fuze. Its effect was, in consequence, of no great importance; the key to the development of its value lay clearly in the invention of a fuze capable of adaptation to requirements. Consequently, in the further development of the experiments carried on with the shrapnel, all manner of new constructions of fuzes were tried; no range of artillery technical science was so fertile in inventions as that of shrapnel fuzes. In 1852, the Breithaupt fuze was introduced into Austria, but was not tried in Prussia till 1855. The marvellous results obtained in the first experiments with shrapnel fire (in consequence of the adoption of this fuze), which artillerists had up to that time never dreamed of, naturally caused very high expectations to be attached to its employment. The artillery of every country imagined that in it it had discovered an element of superiority over those of other countries, as well as an unfailing factor in winning the victory in war. With regard to the supply of ammunition, it may further be mentioned, that, after the wars above named, the amount of case was considerably reduced.

The effective power of field guns during this period, is thus portrayed by the author:—

With solid shot or shell, firing point blank, the greatest range that could be employed in the field in order to gain any result worth speaking of was—for guns of large calibre 1200 metres, for light guns 1000 metres.

Ricochet fire could only be taken into account under very exceptionally favourable conditions. Monhaupt is quoted by the author, who states:—"The science of ricochet fire is a theory constructed on smooth paper and tested on level practice grounds . . . . . Where it has been utilised, the results have borne no comparison with the amount of ammunition expended."

Opinions differed widely with regard to case-fire. The author, however, brings forward many proofs to show that case has not produced the results which were on all sides expected of it. "Gradually the doubts with regard to the great effect produced by case-fire became more general and more confirmed." And Decker says, "The effect of case, in war, can be determined by no method of calculation." The author concludes by saying:—"It is undeniable that case-fire was often the last chance for artillery. On account of the

small effect produced by solid shot against deployed lines and skirmishers, the artillery had recourse proportionately often to case-fire in order to repel attack. That was a tradition of the Seven Years' War, which, owing to the comparatively slow and cumbrous system of tactics, as well as the inferior training of the infantry, was then correct enough; the correctness, however, would necessarily vanish more and more with time.

Shrapnel fire was denominated "case-fire for long ranges." It is well known that to obtain successful results with shrapnel in the field requires a thorough acquaintance with the peculiarities of the projectile and with the theory of its use. This is the reason why opinions on the value of shrapnel have so greatly fluctuated. The highly favourable *data* given by Bormann in the experiments carried out in Belgium, called forth, universally, great hopes with regard to the effect of shrapnel. General Okounef says:—"Shrapnel must give to artillery such a destroying effect, that it will decide the fate of future battles."

In the 4th Chapter of the 1st Part, the author examines the conditions with regard to the effect and mobility of field guns. With regard to effect, the 6-pr. was taken as the minimum; with regard to mobility, the 12-pr. The necessity for increasing the mobility of field artillery had undoubtedly arisen during the period of twenty years. This was, in part, caused by the greater mobility imparted to infantry tactics. The efforts to obtain mobility, indeed, increased beyond the desirable limits, in spite of the valuable opinions of Decker, Grävenitz, Birkenstein, and others, who always maintained "that the primary condition to be attained in artillery must ever remain effect."

The almost universal solution arrived at was, "maximum mobility combined with only necessary effect." And so the state of affairs remained until a successful reaction arose, owing to the increased effects of rifled small-arms. The condition "necessary effect only," then became altered, and brought about a modification of the limit of mobility. The existence of two calibres in all systems of artillery proved that the problem of attaining every requirement in effect and mobility could not be solved with one calibre.

In the 5th Chapter of the 2nd Part, the author gives a very interesting sketch of the development of horse artillery. The most important point here is the controversy between *riding and driving* (*cavalry*) *artillery*.

The lesson attaching to, and to be deduced from, the tactics of horse artillery in action, resolved itself simply into an extreme utilisation of the principles of mobility. The burden of the problem lay in this:—"Rapid and spirited advance against the enemy, and decision of the fight at a given point by a quick and sudden fire of case." Horse artillery went too far, indeed, with this idea, and still ran away after a phantom when *the introduction of rifled arms had long made the carrying out of it impossible.*

The 6th Chapter deals with the organisation, comparative strength, and training of the artillery during this period. Here also a rich field of striking ideas is presented, as well as numerous details with regard to the different systems of organisation in use with the various artilleries of that time. These are more particularly of value to the military historian.

In the 7th Chapter, tactics is treated on.

The principles governing the definition of the "tactical unit," which determined it as the battery, appear then, and also during the entire period, to have contributed greatly to the fallacious scattered employment of artillery.

The author points to the difficulties attending a proper employment of artillery, especially to a correct appreciation of the main requirements—viz., the recognition of the opportune moment, the correct choice of aim, and the increase of fire on the decisive points.

The problem of the formation of masses of artillery met with still greater difficulties. The author illustrates this from works in military literature which occupy themselves essentially with the study of this problem.

Period II. Transition.—From 1850 to 1860.

The more highly perfected and improved system of tactics adopted for fighting in open order, as well as the employment of rifled small-arms, necessarily influenced greatly the uses and importance of artillery. The recognition of the changed conditions themselves, as well as the altered fighting conditions of the infantry, demanded many reforms in the artillery; consequently the ten years from 1850 to 1860 are the most important for, and indeed a turning point in, the development of modern field artillery. During this period, the artillery made the greatest efforts to introduce a new *smooth-bore* field gun, such as might restore to it the importance *it had almost wholly lost since the adoption of rifled small-arms.* At the same time, rifled cannon were slowly and quietly progressing in development as the representative of the new principle which small-arms had raised to so undreamed-of a height. The help which the smooth-bore gun could no longer supply, was furnished by the rifled gun, *and this indeed at the moment of greatest need.* The old principle was exhausted—had outlived its day. Facts had long decided the question; the rifled gun, in its existing stage, had an undoubtedly great superiority over the smooth-bore.

In the 1st Chapter of this part, the author compares the condition of the field artillery with the effects obtained from rifled small-arms about the year 1850, and arrives at the conclusion that the importance of artillery had changed to its *disadvantage.* Delvigne had already stated:—"The introduction of rifled small-arms for infantry will be the scourge of the field artillery. The superiority thereby afforded to the infantry, will assign to the artillery only a secondary *rôle.*" Though Paixhans pointed out as early as 1835 the necessity for the introduction of rifled gun-tubes, and in 1849 pronounced a still more positive opinion on the question, nothing was at that time done to carry out his idea. Matters, therefore, indeed took the course pointed out by Delvigne.

The artillery retrograded to a mere secondary *rôle.* Rifled small-arms fired up to 450 metres with the same accuracy that the smooth bore fired up to 225 metres. The artillery consequently suffered in its power with respect to range, more particularly in the shorter and more effective ranges down to 225 metres; and, moreover, the worst point was that this depreciation struck principally at the case shot (up to the present time so highly esteemed), which sank very considerably in importance, for it became almost useless for the offensive. The fact of this depreciation became only gradually recognised.

The illusions were disturbed by the experience of the wars between 1848 and 1850. Many cases occurred in which batteries were compelled to abandon their positions by the fire of small-arms between the ranges of 300 and 525 metres. The author brings forward a great number of arguments from thinking tacticians, which in the main all concur "that, owing to the long

range of small-arms, guns will scarcely be able to unlimber for the future at case-range."

The ways and means to remedy this evil were therefore examined. This is gone into in the 2nd Chapter. The author acknowledges the efforts made towards an increase of effect by the construction of shell-guns, examines the experiments carried out with the French and Saxon shell-gun, and arrives at the conclusion (as does Waldemar Strenbel in his book, "The 12-pr. Shell-Gun"), that these guns did not answer.

After giving an outline of the efforts made in the artilleries of some other nations towards the invention of a more effective and lighter field gun, the author passes over to the Prussian short 12-pr. He affirms "that with this gun the requirements with respect to increased effect with case must remain unfulfilled;" that after a slight experience of the short 12-pr., loud cries were raised that "the eccentric shell manifest an unmistakeable inaccuracy and error on the practice grounds," and that the new gun failed to answer the main object and requirement—viz., general extension of the zone of effect, commensurate with the increased power of rifled small-arms.

A striking change in ideas occurred, with reference to effect and mobility, at the close of this period. The conviction had forcibly gained ground that "effect" must at once be placed before "mobility," which must consequently be proportionately sacrificed.

In the 7th Chapter of this part, the author gives a sketch of the development of rifled guns. He draws attention to the fact that the question of rifled guns has been raised at various epochs of time, and though it has fallen through—invariably owing to imperfect technical science—has again come to the front since the introduction of rifled small-arms, and now, in spite of all manner of depreciatory opinions, can no longer be kept back. The experiments made by the artilleries of various nations between 1850 and 1860 are spoken of with very great interest. Of these, the author subjects those of the Prussian artillery with rifled breech-loading guns to a more especial evaluation.

In examining the experiments made with the view of determining the class and kinds of ammunition required for rifled guns, it is stated that the shell in all cases replaced the solid shot. The most material reason for abolishing the latter was, however, the conviction, which continually gained more ground, that, for all ranges and purposes in a campaign, the shell was not only sufficient, but indeed was more effective than solid shot. Even in the closing epoch of smooth-bore guns, the solid shot was acknowledged to be ineffective; in 1859 the Austrian artillery had frequently experienced the inadequate effect of solid shot against skirmishers, and had, in consequence, ordered the employment of shell only, with the smooth-bore 12-pr. After these acknowledged facts, the supply of solid shot for rifled guns could obtain no justification.

With reference to case, the author says:—"The effective power of case—to which an undue importance continued to be attached—became less in proportion to the smaller charges employed with rifled guns, compared with smooth-bores." The opponents of rifled guns endeavoured later to put forward this evil as a fundamental defect, which ought to place in question the utilisation in war of these guns, mainly as field pieces.

The arguments of military critics, collected in Chapter 10, are of importance. Paixhans said:—"The solution must be discoverable; it must be

possible." Sir Howard Douglas:—"Success in future wars will depend on firing at long ranges." Cavalli:—"The old guns must in every respect give way to the new. Artillery must thus regain its superiority over small-arms. The elongated shrapnel of rifled guns are of especial value."

The La Hitte system, in connection with effect and mobility, is sketched at the end of this part; after which, the organisation, tactics, training, &c., of artillery are examined. It may be especially noted that in the distribution of the artillery in the *ordre-de-bataille*, the advantages of forming a divisional artillery were dismissed, and the principle was laid down that, in tactics, the combination of artillery power was essential.

Period III. From 1860 to 1866.—Carrying through of the Armament of the Field Artillery with Rifled Cannon.

This period is bordered by two wars, each of which constitutes a turning point in the history of the development of rifled field guns. The campaign of 1866 settled the last doubts connected with the introduction of rifled ordnance. A very bitter controversy arose on the question of calibre, in which the old dispute "effect and mobility" again broke out. In the solution of this question, a material gain was found in the introduction of the rifled system; for the state of affairs became this—the principle of effect gained the zone disputed by the actually existing light calibre, while the principle of mobility gained the *terrain* momentarily snatched away by the heavy calibre. Here the French muzzle-loading and the Prussian breech-loading systems divided the laurels.

In the 1st and 2nd Chapters, the author gives a sketch of the experiments carried out, during the period dealt with, with the object of fixing the systems. The development of the Prussian system is presented in detail. Any person desirous of studying the immense difficulties to be surmounted in the formation of a new field artillery *matériel*, of informing himself on the details of planning and carrying out artillery experiments, or, again, of understanding with what deep thought and consideration all questions referring to rifled field guns have to be proved and weighed, must not shrink from the trouble of examining this portion of Müller's work.

The *data* with reference to effect and mobility in connection with rifled field guns, found in the 3rd Chapter, are official, or at all events taken from the best works of modern times; there can, consequently, be no doubt of their accuracy. Here, the author adds a short comparison between the effect of rifled and that of smooth-bore field guns. As this *résumé* is compiled with great clearness, and, moreover, in it the author affirms his complete accord with the writings of Maresch and Nicaise, we cannot do better than give the reader some extracts:—

(*a*) "The light rifled field gun fires shell of an average weight 1·68 k.g. greater than the weight of the solid shot of the corresponding smooth-bore gun, and somewhat greater than that of the 12-pr. shell.

(*b*) "The heavy rifled field gun fires shell with an average weight 2·54 k.g. greater than the weight of the 12-pr. solid shot, and 1·63 k.g. greater than that of the 15-pr. shell.

(*c*) "The shrapnel of the rifled gun contains a considerably larger number of bullets than that of the corresponding smooth-bore gun.

(*d*) "The number of bullets in the case shot employed with the rifled gun, compared with the number in the shot employed with the smooth-bore gun, is either quite immaterially smaller, or the same.

(*e*) "Up to a range of about 750 metres, the velocity of the shell and shrapnel is somewhat less than that obtained with the smooth-bore guns; beyond 750 metres, it is considerably in excess of it.

(*f*) "Against fixed and living objects, the shells of rifled guns are very considerably more effective than the solid shot and shell of smooth-bore guns.

(*g*) "Up to 800 metres, the extent of the zone covered by the shell with rifled guns is inferior to that covered by the missiles of smooth-bore guns; beyond 800 metres, it is immensely greater.

(*h*) "Apart from the longer maximum ranges of rifled guns—which are from 1500 to 2500 metres greater than those of smooth-bores—the distances applicable for a rapid decision have been extended from 600 to 800 metres.

(*i*) "In consequence of their increased accuracy, rifled guns exercise at 900 metres double, at 1200 metres four-fold, the effect of smooth-bores; at 3000 metres, the same effect as the smooth-bore at 1200 metres.

(*k*) "The limit for the employment of shrapnel has been extended with rifled guns from at least 600 to 900 metres in comparison with the smooth-bore. On an average, the rifled gun firing shrapnel at 1500 metres effects the same results as the smooth-bore at 800 metres.

(*l*) "The effective range of case with rifled guns has retrograded from 100 to 150 metres. Within the effective range, the result obtained is, however, but little inferior to that of smooth-bores, and is adequate to the present requirements.

(*m*) "By reason of the increased range of rifled guns, the opportunity of bringing an effective concentric or cross-fire on numerous points of the field of battle, both at absolutely, as well as relatively, longer distances than was possible with the smooth-bore, has been regained.

(*n*) "The introduction of rifled ordnance has, in fact, levelled the one-sided conditions which had arisen from the armament only of the infantry with rifled small-arms.

(*o*) "It will be necessary to augment the artillery."

In the 4th Chapter of this part, the author has collected and set forth the arguments bearing on the importance, effect, and mobility of rifled field guns, according as these factors have been regarded with doubt or with absolute opposition. "It might at the present time appear desirable," says Major Müller, "to leave untouched an episode resulting from the development of rifled guns, the course of which has been very aptly pronounced by military literary journals to be 'an empty literary movement.' But it is impossible for the historian to pass over a really 'colossal error' in silence, which for a time, indeed, gained a certain ground, and an acquaintance with which may, in future, serve as an example of warning. At the head of this movement

stood the former Saxon artillery officer Strenbel, who published a series of papers under the name of Arkolay, the last of which may be denominated pamphlets."

In the remaining chapters of this part, we have the arguments on the organisation and tactics of artillery, which may here be passed over with the greater confidence that the generality of what is brought forward is at the present moment in operation and universally recognised.

Period IV.—From 1866 to 1870.

The campaign of 1866 brought rifled guns into the field for the first time in great number. On the one side, were more especially the Austrian muzzle-loaders—acknowledged to be the best muzzle-loading system—and with them, in the smaller German armies, the Prussian 9 c.m. breech-loader. On the other side, were the Prussian breech-loaders. Both sides employed also smooth-bores—viz., the short 12-pr., the 15 c.m. howitzer of Hanover, &c.

The general conclusion arrived at, even from the commencement of the campaign, is this—that material support was looked for from artillery combats and from the deciding effect of artillery fire. The author in this particular coincides completely with Maresch, who says:—"The time had come, when the *morale* attached to rifled guns was greater than the excellence of the gun itself." "The smooth-bores effected virtually nothing in the campaign. In comparison with the rifled guns, they were powerless, and could seldom be advanced sufficiently forward to be brought into play against other arms." The rifled breech-loading pieces, however, did not fulfil the certainly too high expectations placed on their effect. What was more easy than to decry this effect? Meanwhile, the Austrian artillery even, which fought the battle of Königgrätz for a long time alone and with success, and later checked the pursuit, in which it not only to a great extent sacrificed itself, but undoubtedly had to put forth the greatest efforts—even it was not permitted to enjoy its glory without alloy, for it was attacked by its own army. "How firmly stood the much-vaunted Prussian breech-loading artillery," says Major Müller, "beside the Austrian artillery."

In the 1st Chapter, the author sketches the development and change in the systems after 1866, and at the same time touches on the introduction of mitrailleuses, to which he refuses to attach any special importance in the field, though he acknowledges the moral effect in many cases, more especially at the commencement of a campaign.

The 2nd Chapter is occupied with the combated question—*bronze or cast-steel?* Supported by numerous arguments and by extensive experience, gained on the practice ground as well as in the field, the author arrives at the conclusion that steel is preferable for rifled tubes. "Only a limited number of the Prussian bronze 8 c.m. pieces were employed in the war of 1870–1, therefore there was no opportunity for detecting defects of a peculiar nature. On the other hand, it has been proved by further experiments, that bronze tubes become comparatively rapidly worn out—*i.e.*, run at the muzzle with firing, and, in consequence, lose their accuracy much more rapidly in comparison with steel tubes."

The author again recalls the fact, that steel tubes gained the great successes

of the late war, that they held out under a very great number of rounds without losing accuracy, and that not a single piece burst.

In the two following chapters, the author discusses the changes in the ammunition, and also the various views which arose during this period on the effect and importance of rifled field guns. The following lines are quoted from him:—

"The shell remained the principal projectile. The improvement effected in the fuze adaptation was undeniable. The larger angle of incidence resulting from the firing at long ranges had, further, been the cause of the effect of the shell being incompletely developed."

A closer examination into the causes which had exercised an unfavourable influence on the effective power of shell, led to improvements which restored confidence to this class of projectile. The war of 1870–1, therefore, also justified in an unexpected degree the confidence placed on shell-fire.

Shrapnel, in spite of very warm controversies, quickly gained the confidence of artillerists. In November, 1870, the amount of shrapnel was increased in Austria to one-third of the total ammunition equipment. In the Swiss artillery shrapnel gained favour daily. The "Militär-Zeitung" of 1867 said:—"Shrapnel is the missile of the future; even case will be placed in question when compared with it." Indeed, so much value was attached to shrapnel, that in 1870 General Vigneau demanded it as the principal artillery projectile. In Prussia, after the experiments of 1869, the introduction of shrapnel with the modified Richter fuze was ordered for rifled field guns in the spring of 1870. The sudden outbreak of war in 1870 unfortunately prevented its being practically tested in the field; a few batteries only received shrapnel, and then only as a supplementary ammunition, which was employed in isolated cases.

Major Müller expresses the idea that the fuzes constructed since, and tested with such successful results, together with the increased training in the art of shrapnel fire, have made so much more powerful an effect possible, as to require that it should attain the same high importance which has resulted with the common shell.

With regard to case-fire, the author says:—"In spite of all theoretical arguments, and the brave efforts of the horse artillery,* the war of 1866 manifested the utter worthlessness of case-fire when opposed to rifled small-arms. If the Prussian batteries—which had a good case gun, and entered into the war with the best intention of employing it in offence—in no case succeeded in making use of it, then, not only was this question solved for all time, but the use of case-fire in the offensive was proved to be worthless." "Case could be only regarded as the last resource of artillery—*i.e.*, for self-defence up to 450 metres—and could, in consequence, be only carried in small proportion." The extreme superiority attached to case, diffused by the adherents of Arkolay, arose for the most part from the complete defeat of the Austrian infantry and artillery by the Prussian infantry. The false ideas arising from these circumstances led to the conviction that a powerful support was essentially required against such infantry, which could only

* It must be remembered that the Prussian horse artillery in 1866 was exclusively armed with smooth-bore 12-prs.

be found in case-fire. The erroneous impression formed by the ineffective results of case-fire with rifled guns, led at that time to their total rejection. Here, the impossibility of the use of case, in view of the long range of rifled small-arms, was entirely ignored. These long ranges have compelled unconditionally the adoption in tactics of long-range fighting, which cannot be neglected. The conditions requiring, therefore, that the decision of the fight should be brought about at longer distances than formerly, have excluded case-fire being employed in it, and dethroned the case projectile from its former pinnacle, for offensive purposes. No efforts can again raise it to what it was when opposed to smooth-bore small-arms.

In the "Discussion on the general Value of Rifled Field Guns," the author gives a review of the works and writings on this subject published between 1866 and 1870. With regard to Arkolay's pamphlet, "Modern Tactics," Major Müller says, among other things:—"This unheard-of abuse of men who have devoted a great portion of the working powers of a lifetime to the solution of a single task, with honest convictions and decided success, is a sign of the immeasurable and diseased self-love of those modern, much-knowing, but little-capable individuals who have sprung up so numerously in all spheres of life and science, and who find only too many admirers among the wavering semi-wise. The success of Arkolay's writings displays a striking illustration of this, in the matter of the military world." After this, unfortunately, too justifiable outburst, the author cites the works of those men who possessed the talent and courage to bring back to the right path the erroneously impressioned public opinion, and more especially puts forward the book of Lieut. Maresch, of the Austrian artillery, as a very sound work. Besides the above-mentioned writings, the war of 1870 gave, in a practical manner, the most annihilating refutation to this subject, at all events in the matter of the Prussian breech-loaders.

Particular attention is devoted also, in this part, to the horse artillery, and the question of unity of calibre. With regard to the first, the author is of opinion that the war of 1870 cut away all ground for debate on its suitability or superfluity, by proving its peculiar advantages, and the resulting necessity for its existence. He cannot, however, refrain, in speaking of the Austrian horse batteries, from quoting a passage from the "Allgemeine Militär Zeitung," which says:—"That which distinguishes the Austrian artillery above all others, is that it has never acknowledged the necessity for introducing 'riding' artillery. Formerly, the latter possessed advantages; now, it is an over-rated institution, costly and unsuitable. The Austrian artillery is equal in rapidity of movement and endurance to the best horse artillery in the world."

The question of unity of calibre has uninterruptedly accompanied the development of field artillery, and undoubtedly the realisation of the idea would not fail to carry with it great advantages. Even Napoleon I. pointed out that the endeavour to attain this should be the aim of field artillery; and since then, many experiments have been made with a view to realise the idea. After 1866, military literature occupied itself with the question with particular energy, but failed to arrive at a tangible result. The war of 1870–1 cleared up many points connected with it; but the experience gained led to the ultimate conviction that two calibres for field guns were necessary.

In the two last chapters of this part, which bear on the organisation and tactics of artillery, the author examines in detail the many writings published

on these heads, but more especially those of Prince Hohenlohe, General du Vignau and Captain (now Lt.-Col.) Frederich Müller, of the Austrian army. Our readers will be sufficiently conversant with this portion of the more modern military literature, so we may refrain from going into it further. The necessity for an augmentation of the artillery is particularly pointed out. In a tactical point of view, the general idea prevailed that it is important to be superior in artillery to your opponent, even in the first stage of the fight.

Period V. The War of 1870-71.—Experience gained from the Sphere of Field Artillery, and the Deduction resulting from it.

It is known that the superiority of the French rifle made itself at once felt in the early engagements, but the superiority of the German artillery over that of the enemy was just as clearly apparent—a superiority which, moreover, decided the character of most of the battles of the war.

The peculiar character of the artillery fighting on the German side was almost exclusively brought about by common shell, since shrapnel was only used in some artilleries of the German armies. Ranges of 3000–4000 paces and over frequently occurred; the actual limit of range employed in the generality of cases lay between 1500 and 2500 paces. On the offensive, the shortest range to which it was possible to advance was from 600 to 900 metres, and then only under favourable circumstances. At a distance of 600 metres the artillery losses from infantry fire were, as a rule, very considerable; and when opposed to unshaken infantry, great losses were suffered, even at ranges of from 900 to 1500 metres—the batteries being, indeed, compelled to retire. The effect of common shell sufficed, with few exceptions, for all kinds and conditions of fighting.

Case-fire was employed on the Prussian side in about 40 cases, in self-defence. In 20 cases, the object was *directly* gained; whereas, in the others, it was uncertain whether or not the attack was not warded off by other collateral causes.

With regard to the expenditure of ammunition in the battles about Metz, the following facts are known:—

14th August, 2,849 common shell, 6 case; 16th August, 19,638 common shell, 19 case; 18th August, 34,481 common shell, 179 shrapnel, 20 case.

Speaking of the successes of the German artillery, the author cites the Russian Baron Seddeler, who remarks:—"The artillery gained an independence which even exceeded the boldest aspirations of artillerists. It is scarcely possible to effect more than was done by the artillery; the numerous victories are mainly due to its co-operation." The Austrian Major Rosinich says that "the principal share in the destruction and conquest of the French, in all battles and actions, must be ascribed to the German artillery."

The author draws from the experience of this war the following conclusions, as the objects artillerists should keep in view:—

"The necessity of engaging frequently at ranges over 2500 paces, and the possibility of thus attaining undoubted decisive results, make it at all events desirable to extend and enlarge the present capabilities and effect of the guns by, on an average, from 400 to 500 metres.

"The intensity of the effect of artillery fire is capable of increase, by the

utmost utilisation of shrapnel, and by an increase in the number of heavy guns.

"Case cannot be dispensed with for the purpose of self-defence by the batteries, and for critical moments in the fight.

"A minimum of—in round numbers—4·5 k.g. is considered as the necessary weight of the projectile for the light gun; a minimum of from 7 to 8 k.g. as desirable for the heavy calibre.

"Breech-loading guns have shown themselves to be thoroughly practicable in the field, though it is admitted that they require careful handling. Improvement in this direction must, therefore, be aimed at.

"A strong divisional artillery, the employment of artillery in masses, and the utilisation of its effective power by a concentration of fire on the decisive points, must remain guiding principles."

With regard to the old debate of "effect and mobility," the author propounds the firm assertion that the future will see artillery combats fought on an enormous scale, and with an almost unimaginable obstinacy. Under otherwise equal conditions, the victory will fall to the side possessing the most effective system.

In an Appendix, "Retrospect and Concluding Remarks," some additional observations are made in striking language.

The smooth-bore system of field guns might undoubtedly have become further developed. "Whatever might have been the issue of the development," says the author, "the system could never have attained the effective power and capabilities of the rifled system; it was, indeed, only practicable in connection with smooth-bore small-arms. In the present stage of the development of small-arms, artillery with smooth-bore guns would, in fact, be wiped out of the army."

The principal revolution in the condition of field artillery was brought about by the changes in the construction of the projectile.

"The universal transition to projectiles which may be regarded as having the effect of shell, and are employed as such, has become the deciding factor in the effective power of field artillery."

Apart from the change in point of value which the case projectile irremediably underwent, the author also points out that even at an earlier date the representations with regard to its effect were not justified, and arose from the moral impressions caused by ignorance. Decker had already expressed himself strongly on this point:—"Of the various arms, cavalry has the greatest respect for case-fire, the infantry cares less, and the artillery indeed makes nothing at all of it."

It is, again, very correctly remarked:—"The feeling, or consciousness, that there is greater probability of being hit at long ranges; the effect the explosion of a single shell may produce; the wounds resulting from it—all these demand greater moral force than formerly."

Major Müller once more recalls the alternations in effect arising from the successive progress of the rifle and the gun. The very same element which in future will bring the one arm to the front, must, with certain variations, also push forward the other. Now that the tactical employment of modern artillery has become better understood, a conviction of its destructive power, and of its increased value, will in future battles become more and more firmly fixed.

The long range of artillery more especially fits it, in the modern fighting tactics, to shatter from a distance, or destroy the power for offence of, the enemy's principal arm, or his infantry. In the next war, it is probable that the conditions for infantry and cavalry will be equal. Success, however, will attend the side having a superiority in artillery.

In conclusion, the author says:—"One is justified in asserting that mistakes in the employment of artillery in action will in future never, or at all events very seldom, be capable of repair. Once your artillery is conquered, you have small chance of success."

The quantity and quality of the work here sketched out may be gathered from the above extracts. A perusal of it, interesting and instructive in every respect, will certainly not fail to clear up many doubts on the working and powers of modern artillery.

Finally, we must resolve to break off with old, if endeared, prejudices, in order to place no obstacles in the way of the further development of field artillery. We must lend an ear to scientific results, confirmed by practical experience in the field of battle; so that a time may not possibly arrive when we shall discover, too late, that we have not kept pace with the requirements of the age. The motto of artillery must continue to be, "Advance steadily along the accepted path, until the utmost possible perfection is arrived at;" for it constitutes now the true fate of nations and armies.

DESCRIPTION

OF AN

ELECTRIC CHRONOGRAPH,

FOR

THE MEASUREMENT OF MINUTE PORTIONS OF TIME, &c.,

BY

LIEUT. H. WATKIN, R.A.

This chronograph, like several others invented during the last few years, makes use of the properties of the induced current of a Ruhmkorff coil; but I think differs from them in its extreme simplicity and freedom from minute and careful adjustments.

In this instrument, a weight drops freely in air, and the registration (which is entirely effected by the induced spark) does not, as in the Boulengé chronograph, commence from the moment of its liberation, but *during its free fall;* thus avoiding any inaccuracies arising from the ever-varying strength of the batteries, and the electro-magnets in connection therewith. A great advantage also of this arrangement is that any slight error in measuring the distance passed over by the weight is of very small importance compared to what it would be in those instruments which register from the starting point. Thus an error of $\frac{1}{100}$th of an inch at the usual point of registration in this instrument would represent an error in actual time of only $\frac{1}{10000}$th of a second, in the others of nearly $\frac{1}{1000}$th of a second. Moreover, it will register a number of consecutive screens, each registration being in duplicate.

From the fact that the registration takes place during the fall of the weight, it is evident that where very minute portions of time are to be measured, the experiments may be so arranged that the weight, under the accelerating force of gravity, shall have acquired a considerable velocity before the registration commences, and thus any required accuracy obtained.

Before proceeding to the description, I would remark that the instrument here illustrated is an exact representation of the one experimented with; and from being altered and added to, from time to time, is not so elegant in design as it might be.

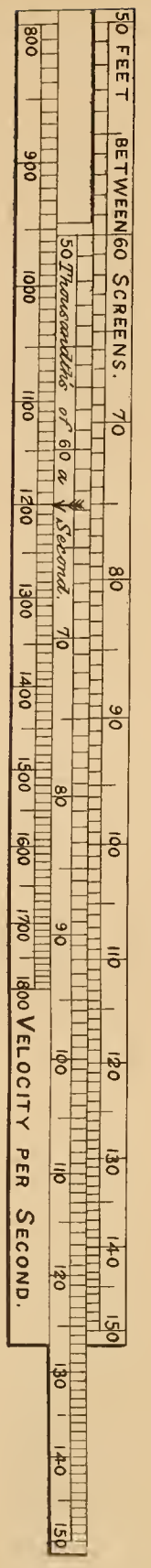
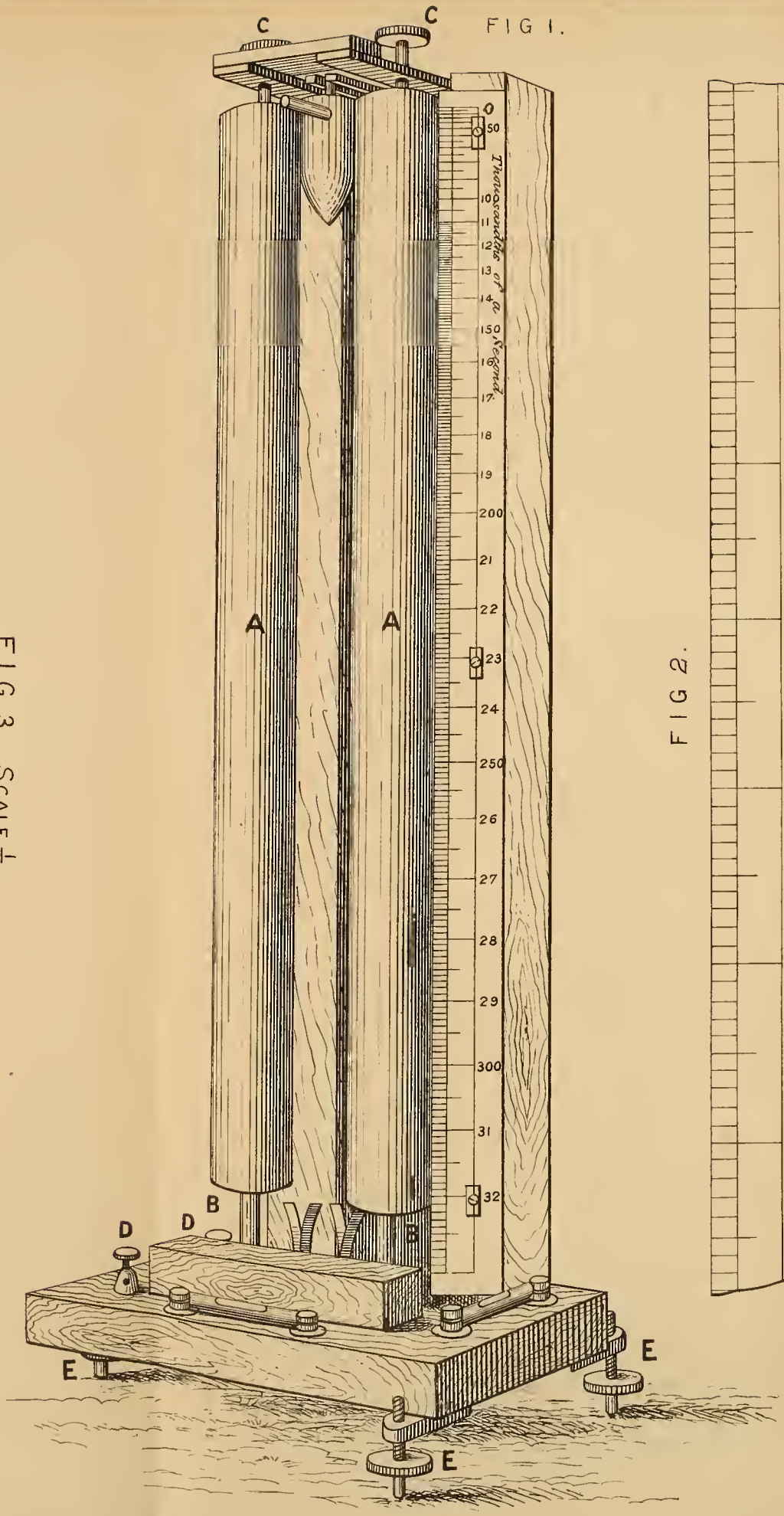


FIG 3. SCALE $\frac{1}{4}$.



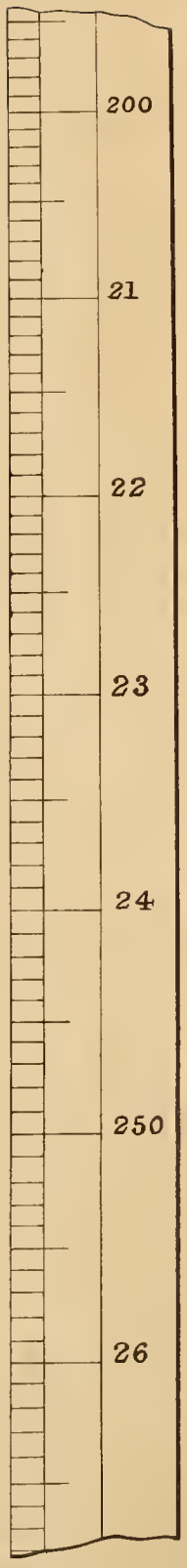
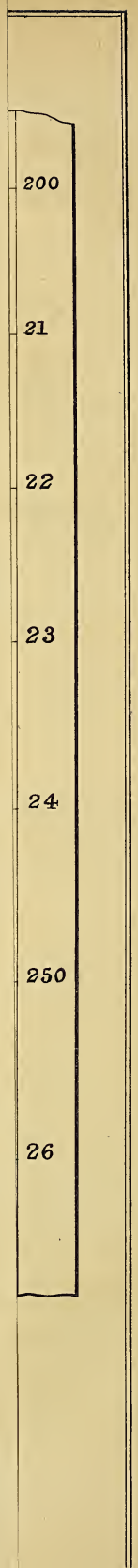


FIG 2.

CHRONOGRAPH.


200
21
22
23
24
250
26

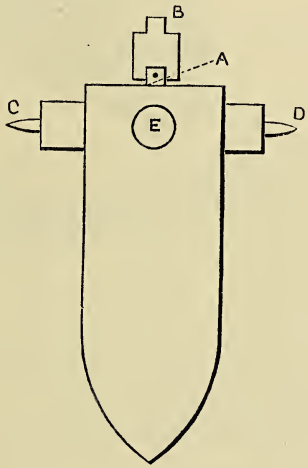
The Instrument

consists essentially of two upright brass cylinders (*AA*), revolving on pivots (*vide* Plate, Fig. 1); those at the bottom (*BB*) being fixed, while the two at the top (*CC*) consist of screws which allow of the cylinders being removed at pleasure. They are carefully insulated from one another, but are in electrical communication respectively with the two binding screws (*DD*). On the bed of the instrument are two spirit-levels, at right angles to one another, by which, with the aid of three levelling screws (*EEE*), the cylinders may be placed truly vertical. Close to, but not quite touching the cylinders, are fixed scales, either of equal parts with vernier, or—what is more convenient for ordinary experiments—a scale of time, divided to thousandths and ten thousandths of a second. On the top, between the two cylinders, is an arrangement for suspending the weight; and at the back, an electro-magnet for releasing the same, to be hereafter described.

The Weight

is of brass, turned with a conical head (Fig. 4). At the base end is screwed

Fig. 4.

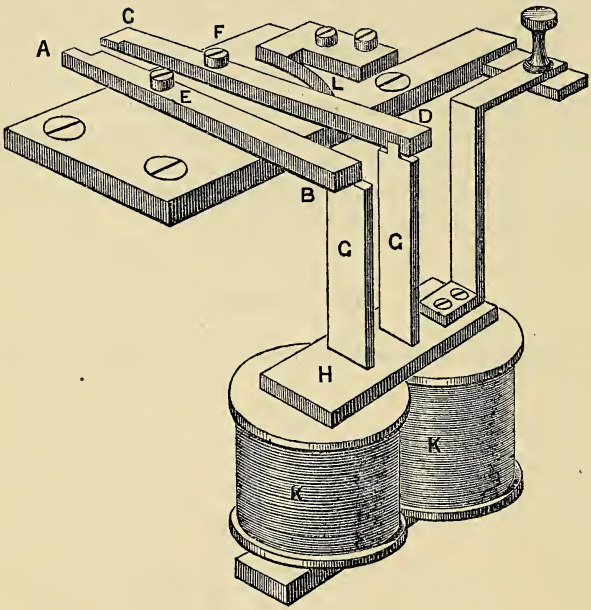


a piece of steel (*A*), in which pivots another piece of steel (*B*); the object of this arrangement being, that when the weight is suspended by *B*, it may still swing freely.

CD is a brass wire, passing through an ebonite tube, and ending in fine points; the length of the wire being slightly less than the distance from one cylinder to the other, to enable the weight to fall freely between them. Two steel arms (*E*), are placed at right angles to the wire, with the object of bringing the weight gradually to rest, by entering two V-shaped springs on the bed of the instrument. (*Vide* Plate).

The weight is fixed and released in the following manner (Fig. 5):—*AB, CD,* are two straight pieces of steel, screwed down at *E* and *F*; the latter (*CD*) being allowed to pivot freely around *F, AB* being fixed.

Fig. 5.



A strong spring (*G*) attached to the keeper (*H*) of an electro-magnet (*K*), can be inserted at pleasure between the steel arms at *B* and *D*; thus causing the opposite ends (*AC*) to close, and grip the steel plate (*B*, Fig. 4) of the weight. In this position, the keeper of the electro-magnet is a short distance from its poles, and when the current circulates is drawn down, bringing with it the steel spring (*G*). The pressure being thus removed from *B* and *D*, the weight is released, and falls between the cylinders. A slight spring (*L*) assists in releasing the weight.

The magnet (*K*) is in electrical communication with two binding screws on the bed of the instrument.

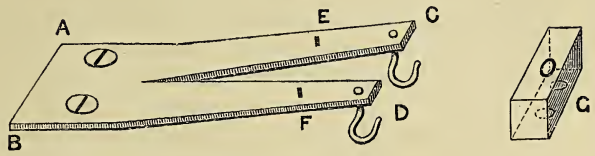
The Screens

are constructed on the same principle as those of Professor Bashforth's—viz., that the electric communication is immediately re-made, after being broken by the shot in passing through, so as to allow the next screen to register, and so on; but they differ slightly in construction, in order to take advantage of the circumstance that the induced spark is brighter and stronger when the primary current is broken between platina points.

To make a screen suitable for experiments for a carbine, cut out rect-

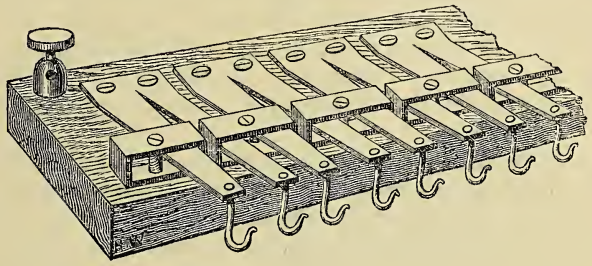
angular pieces of brass (*ABCD*, Fig. 6). Holes are drilled at *E* and *F*, and

Fig. 6.



platina wires about $\frac{1}{8}$ in. long soldered into them, so as to project equally on both sides. At *C* and *D* two other holes are drilled, and pieces of brass wire, bent into the form of a hook, fixed in. They are intended to fasten the threads which press down the spring and are broken by the passage of the bullet, and should therefore be at a less distance apart than the bore of the carbine, in order to prevent the shot slipping through without breaking a thread. Strips of copper or brass are bent in the form shown at *G* (Fig. 6), and brazed at the corners. Inside are soldered small platina discs, at the same distance apart as the points *E* and *F*. The various pieces are screwed on to a board $\frac{1}{2}$ in. thick and about 4 ins. wide (as in Fig. 7), and

Fig. 7.



binding screws attached at both ends. As the threads require to be so close together, weights become inconvenient for pressing down the springs, and a good substitute I have found to be silk-covered elastic, which by its elasticity keeps the springs in perfect contact. It will be evident from the drawing in Fig. 7 that when the springs are all pressed down by the threads and elastic, the breaking of any one will cause the current to be momentarily interrupted, but again renewed almost immediately.

On trying the screens, by fastening short wires (less than 3 ft.) from the binding screws to the primary wire of a coil, however much battery power was put on, no induced spark could be obtained—not even the $\frac{1}{20}$ of an inch, although the coil used in the ordinary manner was capable of producing a spark fully $\frac{3}{4}$ in. long. It was proved clearly that the connections were in perfect order, and that this failure did not arise from the resistance of the wires or screens, as a strong current was passing freely at the time. And here would have been an end of the chronograph, had not a happy thought struck me, after nearly a month spent in experimenting, which

eventually solved the difficulty—viz., that the condenser, which so greatly increases the effect of the coil, should perhaps be placed at the point of rupture of the primary wire. A condenser was therefore made, of the ordinary construction, and of such a size as to fit under the screens. Now, although at least 150 yds. of wire were attached between the screen and coil, sparks passed freely whenever the communication was broken, and with exactly the same battery power that had proved so unsuccessful before. Having thus solved the problem, it became a matter of curiosity to know how the inventors of other chronographs who likewise used the induced current had overcome this difficulty. On enquiry at Woolwich, I found they invariably employed powerful and expensive coils; whereas, by this method, a small and inexpensive one is all that is required.

Theory of the Instrument.

As the weight starts from rest, from a fixed point, and falls freely in air, the rate at any particular moment is given by the formula

$$S = \tfrac{1}{2}gt^2;$$

where S = space fallen through,
g = force of gravity at the place,
t = the time in seconds.

By the aid of logarithms, a scale may be easily constructed, starting from 0 and going as far as the height of the instrument will allow.

Fig. 2 shows a part of such scale, full size, the small divisions representing thousandths of a second. The greater the height from which the weight falls, the larger will be the divisions; so that any accuracy may thus be obtained.

The action of the instrument is simply this:—The weight being released a short time before the gun is fired, descends between the cylinders; the shot, on passing through the first screen, breaks the continuity of the primary wire of the coil, thus causing an induced spark to pass from one cylinder to the other through the brass wire of the weight—this being its shortest path. As the cylinders are covered with smoked paper, a minute spot registers the exact position of the weight at that moment. The weight continuing to fall, as the shot passes the second screen (the primary current being in the mean time re-established), the same result follows; and so on for any number of screens. The distance between the spots, as read off on the velocity scale, gives the time taken by the shot to pass the various screens. By means of the calculating scale shown in Fig. 3, the velocity may be at once ascertained for any distance between screens. It will thus be seen that there are no disturbing influences at work, such as the de-magnetization of electro-magnets, &c., to detract from the accuracy of the result. For a fresh experiment, all that is required is to turn the cylinders slightly round, so as to present a fresh surface of the black paper, and again suspend the weight.

The Calculating Scale

is in three divisions. The upper represents the distance in feet between the screens; the centre, time divided into thousandths of a second; and the lower,

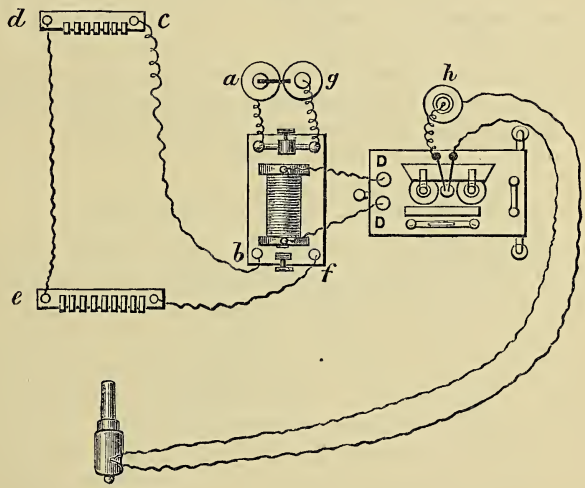
the velocity of the shot per second. To use it, draw out the centre scale until the line representing the time occupied by the shot in passing from one screen to the other is opposite the line representing the distance between the screens; the velocity will be seen opposite the arrow on the lower scale. In the drawing, the distance between screens is 96 ft., the time 80 thousandths of a second, the velocity, therefore, 1200 ft. per second. On the actual scale—which is four times the size of the drawing—the velocities can be read off to half a foot.

For an Experiment,

cover the cylinders with tissue paper (of the best quality, free from holes), and if the experiments are to be in the open air, with no cover for the instrument, it is advisable to choose a bright-colored paper, so that the spots formed by the spark burning away the carbon may be easily distinguished from the white specks of dust which settle on the cylinders. The paper should then be thinly, but evenly, covered with lamp-black, by holding the cylinders either over a smoky lamp or piece of burning camphor, and then carefully replacing them on the instrument.

Place the induction coil close to the left side, and attach wires from the binding screws of its secondary wire to the binding screws (*DD*) on the

Fig. 8.



instrument, which are in connection with the cylinders; connect up the battery with the coil, and the screens with the primary wire of the same, in the manner shown in the sketch, so that the current shall take the following course—viz., from one pole of the battery (*a*) round the coil to binding screw (*b*), then through further screen (*cd*) to the first screen (*e*), back to the coil (*f*), and the other pole of the battery (*g*).

A second battery (*h*) must be placed in connection with the electro-magnet,

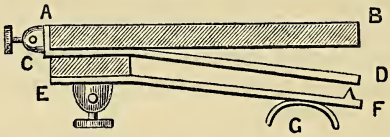
for releasing the weight, and wires leading from the gun attached to the binding screw in connection with it.

Everything being now in readiness, carefully level the instrument, and suspend the weight. On the gun being fired (or before, if necessary), the magnet releases the weight, which in falling registers the screens, as before described. As it reaches the bed of the instrument, the steel arms enter the V springs, and gradually bring it to rest.

The cylinders are capable of registering from twelve to fourteen experiments each, after which the paper can be taken off, and preserved for reference by applying varnish at the back.

For releasing the weight when experimenting with a carbine, I have found the following simple device act perfectly. *AB*, (Fig. 9) is a piece of ebonite,

Fig. 9.



to which is attached a brass spring (*CD*). *EF* is another slightly weaker spring, insulated from the former, and to which a crutch (*G*) is soldered, to fit the trigger. These are put in connection with the wires from the electro-magnet. On taking aim, and pressing the finger against *B*, the springs come in contact, releasing the weight; on the pressure being continued, the trigger is moved, and the carbine fired.

By altering the rate at which the finger sets the trigger in action, the first registration may be made to take place at any part of the scale. With a fixed object, such as a gun, this becomes still more simple.

Applications of the Instrument.

An important application of the instrument would be the accurate determination of the rate of revolution of rapidly revolving discs or cylinders. Thus, for example, suppose the right cylinder of the machine is to be set in rapid rotation, and its rate required. All that would be necessary would be to drill a small hole close to the bottom of the cylinder, and insert a piece of ivory; by fixing a light spring to press against the cylinder, the electrical communication would be complete, except at this point. If now the primary current be so arranged as to pass from the coil, through the spring and right cylinder, back to the coil, it is evident that an induced current would be generated each time the cylinder revolved and brought the ivory point under the spring, intercepting the current. The secondary wires being attached, as before described, a spark would pass from one cylinder to the other through the suspended weight; and if the cylinder was put in rapid revolution, and the weight released, a row of sparks would indicate the rate; the distance between any consecutive two, as measured on the velocity scale, being the time taken for one revolution. Similarly, by placing two ivory points equidistant from one another, two rows of spots would mark the rate of each

half revolution, and so on for any number—a great convenience when the revolution is not uniform.

I believe this would be a far more accurate method of determining the rate of revolving cylinders, &c., than those at present employed in chronographs, inasmuch as the force of gravity measures the rate directly, instead of through the intervention of clocks and pendulums; it being a known fact that however slight the contact springs attached to a pendulum, the uniformity of its vibration is deranged.

Many interesting experiments may be made with the machine. A very simple one is to show the accelerating force of gravity. Thus, having attached the secondary wires of the coil as before, suspend the weight, and set the vibrating spring in action (in the ordinary manner for obtaining sparks). A musical note will be heard, the pitch of which does not alter for short intervals of time. Now release the weight, and white spots will be seen down the whole length of the blackened paper, formed each time the vibrating spring broke the primary current. The acceleration will be distinctly seen, the distance between the spots increasing in a regular ratio. On reading these off on the time scale, the rate of vibration will be determined.

By using a tuning-fork of known pitch to break the primary current, the accelerating force of gravity at any place might be determined by the formula

$$g = \frac{2S}{t^2},$$

and the accelerating force at two stations compared.

I have not yet had the time or opportunity of comparing this instrument with others in actual practice; but from experiments I have made, there is little doubt, I think, of its extreme accuracy. Its simplicity speaks for itself. The instrument may be used with any of the ordinary screens, by using a relay to break the primary current, and, as far as I can judge, with perfect accuracy; but this necessitates what I was anxious to avoid—viz., an electro-magnet, whereas, in the method I have adopted, there is no mechanism between the screens and the registration except the Ruhmkorff coil, the action of which can be depended upon with certainty.

In conclusion, I would point out at least three great advantages this instrument has over those hitherto employed, viz.—

Absolute accuracy,
Simplicity,
Small cost.

GIBRALTAR,
May 20, 1874.

EXPLANATION OF LOCK ACTION OF "GATLING GUN."

(*In continuation of paper published in "Proceedings," No.* 8, *Vol. VIII.*)

BY

CAPTAIN J. F. OWEN, R.A.,

CAPTAIN INSTRUCTOR ROYAL GUN FACTORIES.

Action of the Service Gatling Gun.

Since completing the foregoing, I have been enabled, by the kindness of Captain Andrew Noble (late Royal Artillery), of the Elswick Ordnance Company,* to give the attached Plate, showing the development of the cam which causes the reciprocal action of the locks in our service Gatling. The plate also allows one to see at a glance the ten locks, each in a different part of its cycle of action, and shows how the cocking-ring or cam draws back and then releases the hammer and firing pin.

Locks V. and VI. are in section, the remainder in plan. The line *ab* across the sections of the ten barrels denotes the commencement of their rifling.

The curved gun-metal cam *AA*, as well as the spiral steel cam or cocking-ring *R*, is stationary; and as the spindle carrying lock-chamber with locks and cartridge-carrier revolves, the following action occurs:—

At I. a cartridge has just dropped on cartridge-carrier in front of lock.

At II. it has been a little pushed forward, as the base of the lock advances up the curve of *AA*.

At III. and IV. we see the cartridge pushed into the barrel.

At IV. the projecting stud of the hammer (shown in each lock by a dotted curve) also comes in contact with the cocking-cam *R*.

At V. the base of the lock has reached the flat part of the cam, the spring has been fully compressed, and the cartridge pushed right home.

At VI., the stud of the hammer being released from cocking-ring, the needle flies forward and explodes the cartridge. The base of the lock at that time rests against a plate of steel let into gun-metal cam at *SS*.

At VII. the lock begins to retreat, its base being forced down the opposite curve of cam. The extractor commences to extract empty case.

At VIII. and IX. the empty cartridge-case is still further withdrawn; while at X. the case has been extracted, and the lock itself, having been drawn clear of the barrel, is ready to pass again to position I.

Thus it will be seen that, during each complete revolution of the barrels and lock-chamber, every lock in succession loads, fires, and extracts a cartridge-case; so that ten shots are fired in each revolution.

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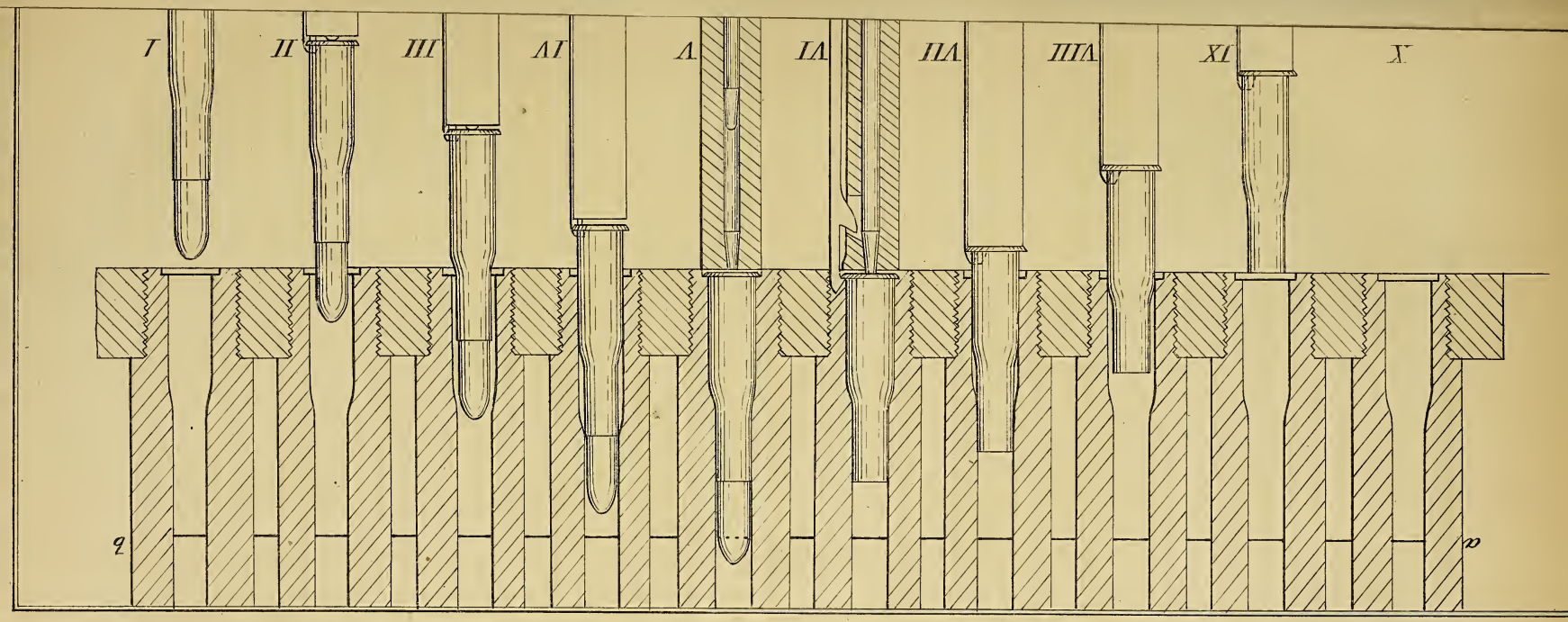
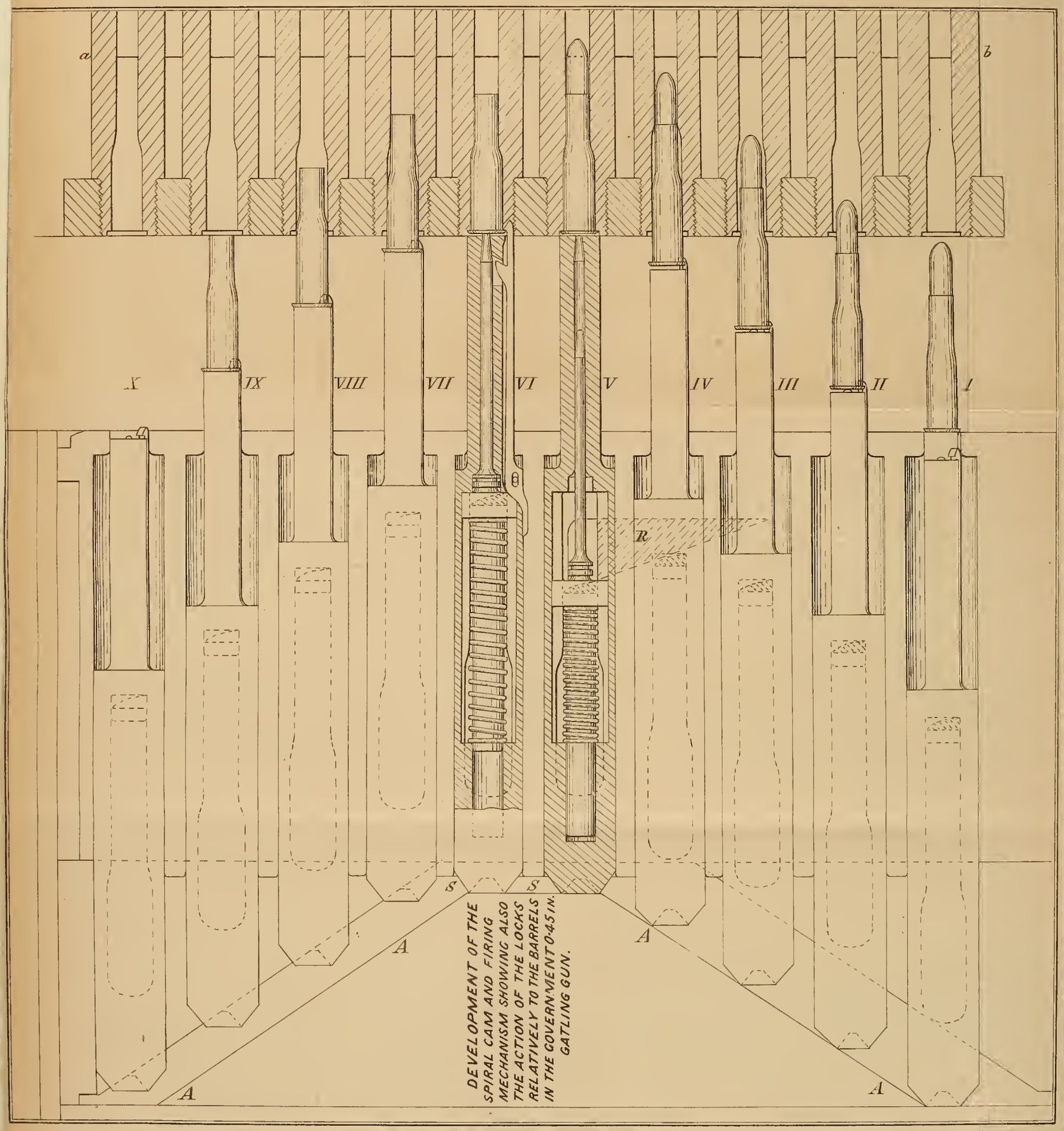
* Captain Noble very kindly had the drawing made, from which the plate was reduced and lithographed.


I
II
III
IV
V
VI
VII
VIII
XI
X
q
p



DEVELOPMENT OF THE SPIRAL CAM AND FIRING MECHANISM SHOWING ALSO THE ACTION OF THE LOCKS RELATIVELY TO THE BARRELS IN THE GOVERNMENT 0·45 IN. GATLING GUN.

REPORT OF TRIAL

OF

"FIRE-PROOF GUNPOWDER MAGAZINES."

BY

MAJOR V. D. MAJENDIE, R.A.

H.M.'S INSPECTOR OF GUNPOWDER WORKS.

(Communicated by permission of the Home Secretary).

---

23 Victoria Road, Old Charlton, S.E.,
30th November, 1872.

Sir,

I have the honour to report that, in accordance with the authority conveyed to me in your letter of 21st August, 1872, No. 14,819, I carried out, on the 9th and 10th October last, a series of experiments with some small fire-proof gunpowder magazines designed by Messrs. Milner and Co., of Liverpool.

Object of experiments.

The object with which these experiments were instituted is explained in my letter to you of 29th July, 1872, in which I recommended that the experiments might be made. As this letter fully describes the circumstances under which this enquiry arose, I have thought it desirable to append a copy of it to this Report. (See Appendix A.) It will be observed that the use of these fire-proof magazines is suggested in the case of retail dealers—or persons who, having no well-isolated store, are compelled to keep their powder in, or in the immediate vicinity of, their dwelling-houses, where, unless the magazine be fire-proof, the gunpowder is exposed to the risk of being exploded by a fire which may occur in or extend to the immediate neighbourhood of the magazine.

Necessity for providing against explosion of powder in retail dealers' and consumers' stores in the event of fire.

In the course of my inspections, I have come across many instances in which the powder is so stored in dwelling-houses, warehouses, &c., that it would be almost impossible to rescue it from explosion in the event of a fire breaking out on the premises or in contiguous buildings.

It is a very common practice to store gunpowder in a room or cupboard near the top of a house, with the idea that if it does explode there it will do comparatively little damage.

This view is so far sound, that an explosion near the top of a house would unquestionably do less harm than one near the bottom; but such an explosion would be far from harmless, and powder so stored is exceedingly difficult to get at in the event of fire, while the carrying of it up and down stairs is objectionable. In many places that I have visited, the powder is kept in cupboards at the back of the shop, and with no sort of special protection; and in the mining districts the miners are very fond of keeping a barrel (frequently not "headed-up") *under their beds!*

As the law at present stands, it is open to any dealer (and no license is required to deal) to keep up to 200 lbs. of gunpowder anywhere and anyhow, and without supervision of any description.

As stated by me in my Report of 16th May, 1872, on the Revision of the Gunpowder Law, "the amount of damage which may be done in a crowded neighbourhood by the explosion of this amount of powder—or even of one-half this amount—is very great indeed. 200 lbs. of gunpowder exploding in a dwelling-house would almost certainly destroy it completely, and probably seriously damage neighbouring houses. In the case of the explosion which took place last November at Stubshaw Cross, two cottages were destroyed, one person was killed, and eight persons were seriously injured by the explosion of about 27 lbs. of blasting powder. At the explosion which occurred at Messrs. Young's shop at Stirling, last September, an explosion of about 30 lbs. destroyed a house, and did damage estimated at about £2000. At the explosion which took place in Manor Street, Chelsea, in October last, about 20 lbs. of powder exploded (as far as I could ascertain when collecting materials for my Report upon the subject), destroying a storehouse, and blowing down one or two brick walls, besides breaking the windows and injuring the roofs of adjoining houses.

At an experiment which I made a few months ago at Chatham, 50 lbs. of powder, placed against a brick wall in the open, not merely blew a large breach in the wall, but destroyed the windows of a cottage about 40 to 45 yds. off, and stripped some of the blinds from the rollers.

To these instances I may add the case of a recent explosion of gunpowder at Stowmarket, when two persons were killed and the back of a house blown out by about 5 or 6 lbs. of powder only.

It cannot, therefore, be disputed that the quantity (200 lbs.) which may now be kept by a dealer without a license—or, indeed, the quantity (50 lbs.) which may be kept by any person, whether a dealer or not—is sufficiently formidable to make it a matter of importance that the powder so kept should be stored in some place where it is not exposed to the risk of fire.

This can only be done in one of two ways:—

(*a*) Providing a magazine so well isolated that it is not liable to be fired by a conflagration in adjacent buildings.

(*b*) Providing a fire-proof magazine.

The former of these alternatives is unquestionably to be preferred; because the isolation which secures the magazine itself against external risks, goes a long way towards securing other buildings from the effects of those internal sources of danger which can never be wholly eliminated from a gunpowder magazine.

But this alternative is not always possible; and if the retail trade is to exist at all, it is one which could not be compulsorily imposed. In fact, the proportion of retail dealers who could provide a well-isolated store is very small indeed; and even if the retail dealers could be disposed of, there would remain the private consumers—gunmakers, sportsmen, and others—who frequently require to keep in their houses an amount of powder sufficient, if not properly stored, to constitute a serious element of danger.

There is another point of view from which the question should be considered. It must be evident that the storage of gunpowder in and about dwelling-houses and shops in such a way that it is exposed to the risk of explosion by fire greatly increases the risk of the firemen and all engaged in extinguishing the conflagration. The knowledge that a quantity of gunpowder was so stored might easily paralyse the efforts of the firemen, and cases might arise in which the Superintendent of the Brigade might be justified in refusing to expose his men to the desperate risk of entering a burning building containing a quantity of gunpowder. Some of the Superintendents of Fire Brigades have furnished me with particulars of cases which have occurred within their knowledge in which either explosions from this cause have actually occurred or have been narrowly escaped.

The following abstracts from the Manchester Fire Brigade Reports, with which Mr. Tozer, the Superintendent of that Brigade, has favoured me, illustrate very effectively the nature and extent of the risks upon which I am insisting:—

Abstract from Manchester Fire Brigade Report.

"*December* 19*th*, 1864.—A fire occurred at A. Cadden's, Gunmaker's Workshop, No. 5 Brook Street. Before a jet could be attached, three heavy explosions of gunpowder took place, scattering bricks and the contents of the shop in all directions; part of the front wall and sides was blown out, and the rest of the building was in a very dangerous state. Having been informed that a large quantity of gunpowder was stored on the first floor, the Superintendent was convinced that if it exploded it would do serious damage to the neighbourhood. The fire was soon after sufficiently subdued to send one of the firemen into the first floor to search for the gunpowder.

"Near the partition wall were five casks of loose gunpowder, which were brought into the street.

"One of the casks had been broken by the explosion, and part of the contents was spread upon the first floor. Upon examining the *debris*, several cases of gunpowder and cartridges were found.

"Before the arrival of the Superintendent, there were several explosions of a large quantity of fireworks."

"*November 4th*, 1868.—A fire occurred at A. Shier's, *Silk Trimming Warehouse*, 13 Dyche Street, Rochdale Road.

"The basement floor was occupied by Mr. Lancashire, Chemist, and contained a quantity of oil, saltpetre, resin, and *eight extra-large casks* of loose gunpowder, which was only damaged by water, although the flooring—which was 3 ins. thick—was burned through in four places. The fire was extinguished in about one hour."

"*March 18th*, 1871.—A fire occurred at J. J. Salis', Printer's Workshop, No. 1 Spring Gardens. On his arrival, the Superintendent was informed that a quantity of gunpowder was stored between the roof and ceiling *over the rooms on fire*. The Superintendent and Chief Engineer found about 1 cwt. in casks and cans, which were removed into the street, and afterwards to the Detective Office. The fire was extinguished in about one hour."

Many cases could be added to these. I myself was present at a fire at Inverness last September, when a cry was suddenly raised that there was powder in the building. Fortunately, it was found possible to get it out of the building and convey it to a place of safety.

Last October, an explosion of gunpowder from a fire occurred in Chichester—time having permitted only the removal of a portion of the store before the fire reached the magazine.

In October, 1871, an unexpected explosion of gunpowder occurred at Chelsea, while the Fire Brigade were in the act of extinguishing a fire which had broken out on the premises of Mr. Monk. The explosion occasioned the greatest alarm, and a good deal of serious damage, frightened the horses of the fire-engine, and caused them to run away, knocking down and injuring several persons.

These instances will serve to establish that the risk from the unsafe storage of gunpowder in places where it can be reached by fire is a real one. Indeed, it must be a subject of surprise to those who are acquainted with the practice of the retail trade in this matter, that fatal explosions from this cause do not much more frequently occur.

It follows from the above, that if a fire-proof magazine, to contain a small quantity of powder—up to, say, 100 lbs., or 200 lbs.—can be provided at a moderate cost, its adoption would be beneficial to the trade and conducive to the public safety.

Moreover, such magazines would seem to possess advantages which would recommend their use on board yachts and vessels, where small quantities of powder are often required to be carried, and where it is not considered worth while to go to the expense of providing a "drowning arrangement" for the magazine.

Influenced by these considerations, I obtained your authority to carry out experiments to test how far a fire-proof magazine which Messrs. Milner and Co. had submitted to my notice fulfilled the above conditions.

It was in the first instance necessary to obtain some data upon which to work. What limit of resistance should be assigned to justify the acceptance of a magazine as "fire-proof?" I thought that I could not do better than apply to the Superintendents of the Fire Brigades of our chief towns for their opinion as to what constituted "fire-proof."

As to meaning of the expression "fire-proof," in its application to a magazine.

Their answers varied considerably, but none of them assigned a higher time than six hours. I accordingly took this as the basis, and informed Messrs. Milner that their magazines must be capable of resisting an intense fire for at least six hours; and in the event of other safe makers submitting "fire-proof magazines" for trial, I am of opinion that this test should be adhered to.

Messrs. Milner and Co. were also informed that the whole of the expense of the trial must be borne by them—a condition which they accepted. Under these circumstances, and having obtained the permission of the Secretary of State for War to carry out the experiments on the Woolwich marshes, the experiments were fixed for the 9th October.

I append the programme which was drawn up for the occasion. (Appendix B.)

Nature and construction of magazines submitted for experiment.

It will be observed that it was proposed to test four safes, one of them being made more resisting than the others, and being designed by Messrs. Milner to resist fire for eight or nine hours.

Drawings, and a specification showing the construction of the magazines designed to resist six hours, are appended. (See Appendices C, D_1, D_2, and D_3.)

The magazine which was designed to resist eight or nine hours, differed from the others only in having 6-in. chambers; the door being proportionally thickened.

The whole of the magazines had an internal capacity of $19 \times 14 \times 16$ ins. $= 4256$ cubic inches, and were intended to hold 100 lbs. of powder in canisters.

The principle of these magazines is that of filling the chambers with a vapourising material, such as alum, mixed with a certain proportion of non-vapourising, non-conducting material, such as sawdust. The original idea was, I believe, to fill the chambers with water, closing a number of holes in the interior with fusible plugs (of bismuth); when the plugs were fused by the heat, the water flowed into the interior, wetting the contents and rendering them impervious to heat for a considerable period.

This arrangement, ingenious as it was, was open to some practical objections. For example, the metal of the safes gradually deteriorated under the influence of the water, while the freezing of the water within the chambers was apt to injure the containing case. The present system, which I gather from the reports of a trial which took place in the Court of Queen's Bench,* was originally invented and patented by a member of the present firm, is a more scientific application of the principle above mentioned.

* Milner *v.* Harrison.

That is to say, the water, instead of being present in the shape of water, exists as water of crystallisation in the alum—which is, in fact, composed of about half its weight of water. On heat being applied, the water escapes as steam, through a number of fine holes, into the interior of the safe, wetting the contents, and at the same time keeping the interior comparatively cool. The patentees claim in their specification "the exclusive use of any matter or thing evolving moisture on the application of heat." The principle of action—whether alum or any other similar material be employed—is the same. It consists in keeping down the temperature of the interior by vapourisation, and at the same time, by wetting the contents, rendering them less liable to injury by fire. Some experiments on a small scale had previously been made to test the applicability of this principle to the preservation of gunpowder from explosion by fire. It was believed that the steam preceding the inroads of the fire would so completely saturate the powder as to destroy its explosive properties; and the results of such experiments as had been carried out appeared to confirm these expectations.

However, no experiments of sufficient importance to warrant a confident recommendation of these safes as gunpowder magazines had been made, nor had the question been investigated as to how far the advantage of the vapourising principle would be neutralised if the powder were in hermetically closed canisters or cases—such as are generally used for sporting powder.

In order to elicit full information on these points, I determined to arrange the experiments as follows:—

Detail of experiments.

Magazine No. 1 (designed to resist six hours) had placed inside it a small pinch of powder wrapped in paper, and six tin canisters, each containing about 2½ drms. (or about a rifle charge) of sporting powder. The canisters were closed in the usual way. To ensure the powder being distributed at different parts of the magazine, I caused the magazine to be filled with empty canisters, placing those which contained powder at different parts of the heap. The object of placing only small quantities of powder in this magazine was to enable it to be opened (for the satisfaction of the spectators) at the end of the six hours, without danger.

Magazine No. 2 (designed to resist six hours) contained 10 lbs. of powder, in ten 1-lb. canisters, supplied by Messrs. Curtis and Harvey, Hall and Son, Pigou and Wilks, and Lawrence and Son. The canisters, which were of the sorts usually sold, and of mixed shapes and various constructions, were put in unopened; and, as in Magazine No. 1, were disposed at different parts of the interior.

Magazine No. 3 (designed to resist six hours) contained 25 lbs. of powder in an ordinary wooden powder-barrel, "quarter" size, and "headed-up." The powder was the sporting powder emptied from twenty-five 1-lb. canisters of various makers. The barrel was placed upon two bricks in the interior of the case, so as to occupy a position as nearly as possible in the centre of the magazine.

Magazine No. 4 (designed to resist eight or nine hours) contained

5 lbs. of powder loose in an open barrel, and 5 lbs. in five 1-lb. canisters (of Messrs. Curtis and Harvey, and Hall and Son).

In every case I personally superintended the placing of the powder in the magazines.

The above dispositions appeared to me fairly to represent the various combinations which might exist in the storage of powder for trade or private purposes. There was the canister powder hermetically closed up, the barrel powder in a closed barrel, and the same in an open barrel, and the powder in paper.

For the purposes of the experiment, Messrs. Milner had caused to be built four furnaces of brick. The furnaces for Nos. 1, 2, and 3 magazines were circles of brick-work, 7 ft. internal diameter, and about 3 ft. 6 ins. high. In order to provide a thorough draught, the furnaces were built with the bricks omitted at intervals—the open intervals serving as so many blast-holes, or "twyeres," through which the air could pass.

The furnace for No. 4 magazine differed only in being 8 ft. 6 ins. internal diameter. A layer of coals and wood and shavings was placed inside each furnace, the magazine introduced and placed on bricks (so as to increase the draught), and then coals were shovelled in until the magazine was completely covered.

Furnaces 1 to 3 took about five tons of coal each; furnace No. 4 about seven tons.

In order to obtain data with reference to the temperature in the interior of the magazines, there were introduced into each two thermometers (one by Negretti and Zambra, the other by Chadburn) capable of registering up to about 600°. Also, and as a check upon the thermometers, there were introduced a number of sticks of alloys of tin and lead in various proportions, which Professor Abel had ascertained were fusible at different temperatures.

There were 21 different alloys, ranging as to fusibility from 340° to 558° Fahr. (For the details as to the composition of these alloys, see Appendix E.)

The fires were lit (by means of petroleum) as follows:—

No. 1	lit at	10.0	a.m.	9th October, 1872.
" 2	"	10.30	"	
" 3	"	11.0	"	
" 4	"	11.15	"	

The fires soon blazed up, and in a very short time they were burning with intense violence. The excellent draught which resulted from the construction of the furnaces soon produced a fierce glowing mass of fire, which completely enveloped the magazines. I may here mention that the experiments were witnessed by a large number of gentlemen variously interested in the results, and including the Superintendents of the Fire Brigades of Dublin, Manchester, Glasgow, Belfast, Sheffield, Bradford, Leeds, &c., several of whom expressed to me personally their satisfaction with the completeness and searching character of the experiment.

They appeared to agree that no gunpowder magazine could ever be subjected to so intense a heat (the heat, as one Superintendent said, not of a fire, but of a "blast-furnace"), for so long a period as six hours.

Result of experiment with magazine No. 1.

At 4.10 p.m. (or exactly six hours and ten minutes after the first fire had been lighted), steps were taken, by pulling down the furnace, to examine magazine No. 1. With some difficulty the magazine was disengaged from the furnace.

It was found that a hole had been burnt through the *outer* iron of the magazine, at the right hand lower corner—due, no doubt, to the heat, directed by the blast-holes, having impinged upon this part of the magazine. The heat had been sufficiently intense to fuze several of the bricks of the furnace.

The contents of the magazine were intact, except the powder in the paper, which had become damp and inexplosive. The powder in the canisters was dry, except in one instance, when some of the vapour appeared to have penetrated into the canister and *slightly* damped a portion of the powder. However, all the powder in the canisters was explosive, as I established experimentally by firing it. The steam had detached the paper labels from the canisters, and the vapourisation had evidently been entirely satisfactory.

The thermometers registered 210°. None of the alloys were melted.

It appears clear, therefore, that notwithstanding the intensity of the fire, the interior of the magazine had been preserved by the action of the vapourising material at about the heat of boiling water.

It was determined to leave the other furnaces to burn themselves out, and if not consumed or exploded by the following morning, to extinguish them. Sentries were placed on the ground, to warn persons off, and to note the time of an explosion, should one occur.

Result of experiments with magazines Nos. 2 and 3.

On reaching the ground the following morning (10th October), I found that magazines Nos. 2 and 3 had exploded. No. 2 exploded at 2.22 a.m., having resisted the fire 15 hours 52 minutes. No. 3 exploded at 5·45 a.m., having resisted 18¾ hours. No. 4 magazine was still resisting at 9.15, when, as I will presently explain, the experiment was arrested.

On examining the scenes of the two explosions, I found that they had both been of a violent character. The explosions had taken effect in each case more or less in the form of a cross, the sides having furnished the lines or directions of least resistance.

In the case of No. 2, I found the door blown bodily 19 yds. to the front—the fire had burnt a hole completely through it; while to the right, fragments were blown 13 yds., to the left 17 yds., and to the back 20 yds. I picked up one of the canisters which this magazine had contained *unexploded* at about 20 yds.—a circumstance upon which I shall have to comment presently.

The explosion of No. 3 (which had contained 25 lbs. of powder)

was naturally more violent than that of No. 2. The door was blown 64 yds. to the front, and portions of the magazine were blown 32 yds. to the right, another piece 30 yds. to the back, another 40 yds. to the left rear, another 52 yds. to left front.

A piece of alloy, the melting point of which was 482° Fahr., was recovered unmelted and unaffected by the heat.

Result of experiment with magazine No. 4.

No 4 furnace was extinguished at 9.15 a.m., or 22 hours after being lighted.

On being opened, this magazine (No. 4) was found to be in very good condition; a few of the rivets had been drawn by the expansion of the metal, but it was otherwise uninjured.

Condition of recovered powder.

The powder in the canisters was in one or two instances slightly damped. That in the barrel was encrusted, or superficially agglomerated to the depth of about $\frac{1}{16}$th to $\frac{1}{8}$th inch, and Professor Abel's analysis of this powder showed that this crust had sustained a slight loss of sulphur. Beneath the crust the powder was unaltered.

I append (Appendix F) a memorandum on the condition of this and the other samples of recovered powder, with which Professor Abel has obligingly furnished me.

One of the thermometers (Negretti's) registered 250°, the other registered 220°. None of the alloys had melted, nor was the solder on the canisters affected.

Summary of results of experiments.

The result of this experiment must be regarded as eminently satisfactory.

Of the three magazines designed to resist six hours—a more than sufficient time, in the opinion of the Superintendents of the Fire Brigades, to warrant a magazine being considered practically "fire-proof"—one had resisted nearly 19 hours, another nearly 17 hours, and the third, when opened at the end of six hours, had been found to have its contents unexploded.

The magazine designed to resist eight or nine hours, had resisted 22 hours, and then showed no signs whatever of any approaching failure.

Messrs. Milner have thus satisfactorily demonstrated that a magazine can be made which will be practically fire-proof—which will, indeed, resist for a longer period than it would be likely to be called upon to endure, a far more intense fire than in any ordinary conflagration could be directed against it.

Consideration of the causes of the explosion of Nos. 2 and 3 magazines.

It is worth while to consider in what way the explosions of the magazines Nos. 2 and 3 were effected, in order to observe how far the safes acted as had been anticipated. The expectation was that the vapour from the alum would penetrate to, and thoroughly saturate the gunpowder, and thus render it inexplosive. In the case of the powder which was hermetically closed in canisters, it was anticipated that when the temperature rose to about 240° the sulphur would begin to volatilise off, and so leave the remaining powder explodable only at a temperature far in excess of that at which powder containing sulphur explodes.

The first of these expectations was certainly not realised; the

Insufficiency of vapourising process alone to protect a mass of gunpowder from explosion.

second was only partially so. It is quite clear, from the condition of the powder in the open barrel in No. 4 magazine, where the vapourising process was in active progress at the moment when the experiment was arrested, that no such complete saturation of a *large mass* of powder is to be looked for. If a quantity of powder, exposed for 22 hours to the full vapourising action of the alum is saturated only to the depth of from about $\frac{1}{16}$th to $\frac{1}{8}$th inch, it is clear that the non-explosion of the powder is not to be referred to this cause, nor can be secured in this way. The powder in canisters, also, was similarly only partially affected by the vapour.

Volatilisation of the sulphur partially effected when sufficient elevation of temperature had been reached.

As to the volatilisation of the sulphur, there were—as detailed in Professor Abel's memo. (Appendix F)—indications that some partial action of this sort had commenced in the only magazine in which the temperature was registered as that at which sulphur will volatilise. If the thermometer is to be relied upon, the temperature in magazine No. 1 did not rise above 212°, which is about 28° below the temperature at which sulphur melts.

In the case of magazines 2 and 3, we have no means of forming an opinion whether the temperature did or did not rise to 240° (the explosions in those cases having been evidently due, as I shall show, to another cause), and the only powder recovered from these (the canister from No. 2) indicated no change in regard to its per-centage of sulphur.

So No. 4 magazine is the only one which gives any reliable evidence on this point; and in No. 4 magazine the expectation that the sulphur would gradually disappear seems to have been partially realised.

Grounds for believing that there was no gradual or general elevation of temperature sufficient to account for explosion of powder.

There remains, then, to be considered:—Why did Nos. 2 and 3 magazines explode at all? Was the explosion due to a gradual and general elevation of temperature in the interior (in other words, to a gradual failure) of the magazine after the lapse of so many hours? To this question I think a confident reply may be given in the negative, for the following reasons:—

1. Gunpowder will not explode at a less temperature than about 560°. But there was recovered, as stated, from No. 3 magazine, a stick of alloy with a melting point of 482°, and this stick was quite unaltered. Had the temperature of the interior of the magazine risen to the exploding point of powder (560°) the alloy must have been melted.

2. There was recovered, as stated, from No. 2 magazine a canister of powder unexploded. Had the temperature of the magazine risen to the exploding point of powder, it is difficult to see how the powder in this canister could have escaped explosion.

3. Several pieces of canisters were picked up with the solder unmelted—and solder melts at a lower temperature than 560°.

4. We have the indirect evidence furnished by the observed temperatures in the two magazines which did not explode—viz., 212° and 250°, according to the thermometers.

On these grounds I think the hypothesis that the powder was exploded by the elevation of temperature in the magazine must be rejected.

In other words, I feel satisfied that the magazines fulfilled the requirement of keeping down the temperature by means of the vapour given forth by the alum.

To what, then, are these two explosions attributable? The answer is, I think, simple. They were due to the actual burning away of the iron at one point, the consequent penetration of the flame to the interior, and the explosion of the powder reached by the flame. There is direct evidence as to the burning away of the iron, because the door of No. 2 was found, as stated, to be so burnt through; and this was merely an enlargement of the effect which was noticed in No. 1 after six hours—a hole having been burnt through the *outer* case of that magazine. In both instances it appears that this effect was due to the direct impingement of the flame, directed by the blast-holes, upon the iron; for in both cases the hole was burnt on that side of the magazine which was most exposed to the action of the wind.

Explosion due to burning away of iron and penetration of flame.

In short, what happened was no doubt this:—The magazines amply fulfilled the object for which they had been constructed *until the iron was actually burnt through,* when explosions followed from the direct contact of the flame with the powder. It will perhaps be urged that the remedy for this is simple—viz., to make the iron thicker or stronger. To this suggestion I would reply by anticipation,

1st. That no such increase of strength or thickness is necessary, since the resisting power is now considerably in excess of what is really required.

Ground for not requiring any increase or alteration in the thickness of the iron.

2nd. That such an increase of thickness would be disadvantageous, in so far as it would increase the cost of the magazines, and so (in the absence of statutory provisions compelling dealers to provide them) would tend to reduce the number of purchasers.

Moreover, if any purchaser desires an extra-resisting magazine, he can of course obtain one of the strength of No. 4. But for ordinary purposes, a magazine of the type of Nos. 1, 2, and 3 would be entirely satisfactory, and may be regarded as thoroughly fire-proof.

It is to be hoped that it will be found practicable to supply these magazines at a rate which will place them within the reach of retail dealers generally. Messrs. Milner inform me that they have no doubt of being able to supply them (to hold 100 lbs.) for 10 guineas; and considering the great increase of public safety which would result from their general employment by retail dealers, it is a question whether their use for all cases in which sufficient isolation from dwelling-houses, stores, &c., and from the resulting fire cannot be secured, might not fairly be made compulsory.

Desirability of securing general adoption of fire-proof magazines of this or other approved construction, for use in houses and crowded localities.

But in the absence of any provision to this effect, it is desirable that every encouragement should be given to dealers to adopt this

mode of keeping their powder; and where (as in Ireland) the keeping of powder forms the subject of a license, I think the magistrates would exercise a wise discretion in calling upon the licensees to provide fire-proof magazines of this or some other proved construction.

Other makers should receive facilities for establishing the efficiency of any magazines they may submit.

It is of course very desirable not to limit approval to the magazines of a particular maker; and in order to stimulate competition and improvement in the production of these magazines, I think that every safe-maker who desires to submit one should be afforded the same facilities for carrying out an experiment, at his own expense, as were accorded to Messrs. Milner. And in the event of any other maker producing an equally resisting magazine, that also should receive an official certificate of proof similar to that which I propose to give to Messrs. Milner.

Certificate of approval.

The plan which I propose to adopt with regard to the certificate, and in order to secure to purchasers that the magazine they are purchasing is of equally resisting power with those which I tested, is as follows:—

I propose handing to Messrs. Milner a written certificate that magazines made by them, and of a particular construction, as shewn in the signed specification and drawing to be attached to the certificate, have resisted certain tests.

Messrs. Milner will then number each safe, and give to the purchaser a guarantee in duplicate that it is of the construction referred to in my certificate. One of these guarantees will be affixed to the magazine, the other will be handed to the purchaser.

I should propose to follow a similar course in the event of the magazines of any other makers establishing their title to such a certificate.

Considerations as to desirability of enclosing powder in a strongly resisting safe.

There are two points to which I think it desirable briefly to advert before closing this Report. It has been urged that magazines of this sort are objectionable, because, being very strong, they would tend, in the event of an accident occurring, to intensify the explosion. The answer to this objection appears to me simple. An explosion can only occur from external or internal causes. Against external causes, in the shape of fire (and no other external causes need be considered), these magazines have shown themselves to be proof.

As for internal causes, as gunpowder is not liable to spontaneous ignition, it is difficult to see how an explosion could occur (provided, of course, that nothing else but gunpowder is stored in the magazine), except when some person is engaged at the magazine; in other words, except when the door is open. If an explosion occurred under these circumstances, the strength of the magazine would be rather an advantage than otherwise, since it would tend to direct the force of the explosion in the direction of least resistance. Moreover, it may be remarked that in any case the explosion of 50 or 100 lbs. of powder inside a house would be so destructive that it would really matter little whether the injury was a little more or a little less.

The other point is the question of how far a magazine constructed on this principle would retain its fire-resisting qualities. It is of course essential to the permanent success of one of these magazines that it should not gradually deteriorate, from the corrosion of the iron by the vapourising and non-conducting materials with which the chambers are filled; and this point has occupied my consideration. In reply to my enquiries with regard to it, Professor Abel writes to me:—"If the alum and sawdust are introduced in a properly dry state, no destructive action upon the cases need be apprehended; if they are damp or moist, an oxidising action will certainly be established, but unless the moisture present is somewhat considerable, this action will not take place to an extent to give rise to rapid destruction of the metal. There ought to be no difficulty in guarding against the likelihood of such corrosion altogether."

As to the permanently reliable character of Milner's magazines.

Messrs. Milner inform me, in reply to my enquiries whether the alum and sawdust are thoroughly dry before being put in the safes: . . . . . "We purchase the alum with particular care that it is perfectly dry, and the sawdust we keep in a dry store for a considerable time, and when mixed, the composition is perfectly dry." Messrs. Milner have also furnished me with some particulars of safes made on this principle which have resisted fire successfully at periods of from 20 to 30 years after being manufactured.

I therefore see no reason to doubt the permanent resisting qualities of these magazines.

In conclusion, I desire to express my opinion that the general adoption by retail dealers and private consumers of fire-proof magazines, of Messrs. Milner's or some other approved construction, would tend largely to reduce the risks at present existing in connection with the storage of powder in houses, shops, warehouses, and crowded localities.

Conclusion.

I have the honour to be,

Sir,

Your obedient servant,

V. D. MAJENDIE, Major R.A.

H.M.'s Inspr. of Gunpr. Works.

The Right Honourable
The Secretary of State,
Home Department,
Whitehall.

APPENDICES.

A.

Copy.

29th July, 1872.

Sir,

I have the honour to report that I have for some time been making enquiries as to the most effectual means of securing the retail stocks of dealers in gunpowder against explosion, in the case of the burning of their shops or stores.

I have been in communication with the heads of the different Fire Brigades on the subject; and Captain Shaw, Superintendent of the Metropolitan Fire Brigade, has been especially obliging in making suggestions. Some time ago, he referred me to Messrs. Milner & Son—the well-known safe makers, of Liverpool—and in May last those gentlemen communicated with me, by letter and personally, and I have since visited their works at Liverpool, in order to pursue my enquiries still further. The result of those enquiries, and of some experiments which Messrs. Milner have carried out, appears to be that a safe for storing gunpowder—a small *domestic gunpowder magazine, in fact*—may be made which will resist a fire for several hours, and the use of which would be attended with greatly increased safety in the storage of gunpowder in and near houses, warehouses, &c.

Considering that, as the law at present stands, anyone who chooses to sell gunpowder (no license being required), may store as much as 200 lbs. anywhere and anyhow; considering that, as a matter of fact, this quantity of powder (and frequently, I have reason to believe, a larger quantity), is stored in dwelling-houses, shops, &c., without any protection whatever against fire; considering that such storage frequently takes place in densely-populated neighbourhoods; and considering that a very much less quantity of powder than 200 lbs. is capable of doing immense destruction to life and property; it does appear to me that if a system of storing powder in fire-proof magazines could be introduced, substantial public benefit would result. Now, whether such a system can be introduced, depends upon two things:

1. Can a really fire-proof gunpowder magazine (to contain small quantities of gunpowder) be made?
2. Would the cost of such a magazine be such as to render possible or probable its voluntary adoption by retail dealers?

With regard to the second of these points, I have reason to believe, from the enquiries which I have made of retail dealers, that many of them would gladly and gratefully adopt these safes, if they can be supplied at anything like a moderate cost; and I gather from Messrs. Milner that it *would be* practicable to supply them at a cost quite within the means of the more respectable retail dealers—at a cost, that is to say, of from about £10 to £15.

One dealer told me that he would order one of these magazines by return of post, if he could be assured that it would really be an effectual protection against fire. And when it is recollected that the retail trade in powder is largely in the hands of gunmakers and iron-makers—generally persons in a considerable way of business—there can, I think, be little doubt that the expenditure of a few pounds

would not deter them from adopting what would constitute, in fact, a very great protection to their own property.

I am therefore sanguine that if it can be established that fire-proof gunpowder safes can be supplied for retail use at a moderate cost, such safes will, by degrees, come very generally into use.

Moreover, I have suggested in my Report on the proposed revision of the law relating to explosives, that no one should be permitted to sell gunpowder or similar substances without a license; and if this suggestion should be adopted, the result would almost immediately be that the licensing magistrates would require the proposed licensee to shew that he had a safe place for the storage of his powder. Thus the adoption of magazines of this sort would probably in many districts become compulsory. At any rate, I can easily understand the licensing magistrates giving a preference to the dealer who provided a fire-proof safe, by permitting him to store a larger quantity of powder than his neighbour who had no such safe.

On these grounds I am impressed with the importance of assisting in the introduction of fire-proof safes, or magazines, for the storage of retail stocks of gunpowder.

The question is, can such safes be made?

To this question Messrs. Milner have no hesitation in replying affirmatively; and in support of their assertion they have furnished me with properly authenticated accounts of experiments conducted by them some years ago, in the course of which some gunpowder was kept in safes for several hours, exposed to the heat of a most intense fire. Quite recently, also, Messrs. Milner have subjected a safe containing gunpowder to an intense fire for six hours.

The Milner safe, it should be explained, is constructed on the principle of containing a quantity of vapourising material (such as alum), which, on heat being applied, gives forth into the interior of the safe a quantity of vapour, by which the contents of the safe are wetted, and so rendered secure against being burnt or exploded as long as the vapourising material lasts, and that is only a question of quantity.

I have communicated with the heads of the different fire brigades, and have asked them how long they thought a safe of this sort *ought* to be required to resist fire.

To these enquiries I have received several replies, but in no case is a higher time than six hours suggested.

Messrs. Milner are anxious to carry out publicly, at their own expense, a series of experiments to demonstrate the practical value and complete efficiency of these magazines, and I am of opinion that such an exhibition would be eminently useful. The point which I have now the honour to lay before you is this:—It would be a very great advantage if these experiments might be carried on in the neighbourhood of London; and for this purpose there are many sites on the War Office property outside Woolwich Arsenal which would be very suitable. I have the honour to request that application may be made to the War Office for permission to carry out these experiments on (or near) the site which I was permitted to use in 1871, when I made a series of experiments for the Home Office on the blowing up of cartridge sheds—viz., near the range in the marshes outside Woolwich Arsenal. This site is quite isolated, and away from houses, magazines, and buildings of all descriptions; and I will undertake to see that the experiments are carried out in a way to ensure that no danger shall be involved to persons or things. No expense whatever will be incurred by the Government, as the safes and all the necessary materials for carrying out the experiments will be supplied at the Messrs. Milner's own cost. The only thing that it may be necessary for me to ask for is the loan of a few men from the Garrison of Woolwich, to keep the ground, and to afford such assistance generally with regard to the *safety* of the experiments as I might think necessary. If I might have a couple of non-

commissioned officers of the Royal Artillery, and, say, ten gunners, that would enable me to make quite satisfactory arrangements.

A request for the loan of this small party for the day might perhaps be preferred to the War Office at the same time as the request is made for the ground.

I may add that I hope to be able to arrange for the carrying out of the experiments about the last week in August.

It is, perhaps, proper that I should explain that I do not propose to take any responsibility on the part of the Home Office as to the success or otherwise of these experiments. The experiments are not intended to be *conducted* by me at all. What is proposed is, that Messrs. Milner should be afforded an opportunity of experimentally satisfying me publicly, so as at the same time to satisfy the retail dealers, that they can make a small gunpowder magazine quite fire-proof; and for this purpose, seeing the importance of the question, I have the honour to solicit for them permission to make those experiments in my presence on the Government site which I have indicated, and for myself, permission to make use of a small fatigue party, to ensure the safety of experiments which otherwise might involve some risk.

I have the honour to be,

Sir,

Your obedient Servant,

(Signed), V. D. MAJENDIE, Major R.A.,

H.M.'s Inspr. of Gunpr. Works.

The Right Honourable
The Secretary of State,
Home Department,
Whitehall.

B.

EXPERIMENTS WITH MILNER'S FIRE-PROOF GUNPOWDER MAGAZINES.

The following experiments, instituted with the authority of the Home Secretary, will take place, by permission of the Secretary of State for War, on the War Department Practice Range, Plumstead Marshes (outside Woolwich Arsenal), on Wednesday, 9th October, 1872, commencing at 9 o'clock, a.m.

Object of Experiments.

To determine if a magazine or receptacle for small quantities of gunpowder, designed by Messrs. Milner and Co., of Liverpool, is capable of resisting fire and preserving its contents from explosion for several hours.

The opinion of the Superintendents of the principal Fire Brigades in the United Kingdom has been taken as to the time for which a magazine, to be really safe, ought to be able to resist such a fire as it might be exposed to in the shop or warehouse of a retail dealer, or in an ordinary dwelling house. The highest time assigned by any of these officers in their replies is six hours. Accordingly, it is assumed that if

a magazine be able to resist fire for six hours, it will afford all the protection which is actually necessary; and the magazines have been constructed on this basis.

The powder to be placed inside the magazines for the purpose of this experiment will be packed in the two ways in which it is generally stored by retail dealers and sportsmen—viz., some loose, and some in tin canisters—no greater quantity of powder being deposited in each magazine than is considered necessary to test satisfactorily the degree of protection afforded.

PROGRAMME OF EXPERIMENTS.

Experiment 1. Powder magazine large enough to hold 100 lbs. of gunpowder, loose or in canisters. 4-in. chambers, constructed to resist six hours in an ordinary fire. Only a few ounces of gunpowder, loose and in canisters, will be placed in this magazine.

Experiment 2. Powder magazine of the same size and construction as No. 1. 10 lbs. of powder in canisters will be placed in this magazine.

Experiment 3. Powder magazine of the same size and construction as No. 1. 25 lbs. of loose powder in a quarter barrel will be placed in this magazine.

Experiment 4. Powder magazine of same size as No. 1, but with 6-in. chambers, and constructed to resist fire for from 8 to 9 hours. 5 lbs. of powder in canisters, and 5 lbs. loose, will be placed in this magazine.

Materials have been provided to keep up the fires from 8 to 10 hours.
The temperatures inside the safes will be registered by thermometers.

V. D. MAJENDIE, Major R.A.,
H.M.'s Inspr. of Gunpr. Works.

HOME OFFICE, WHITEHALL, S.W.,
4th October, 1872.

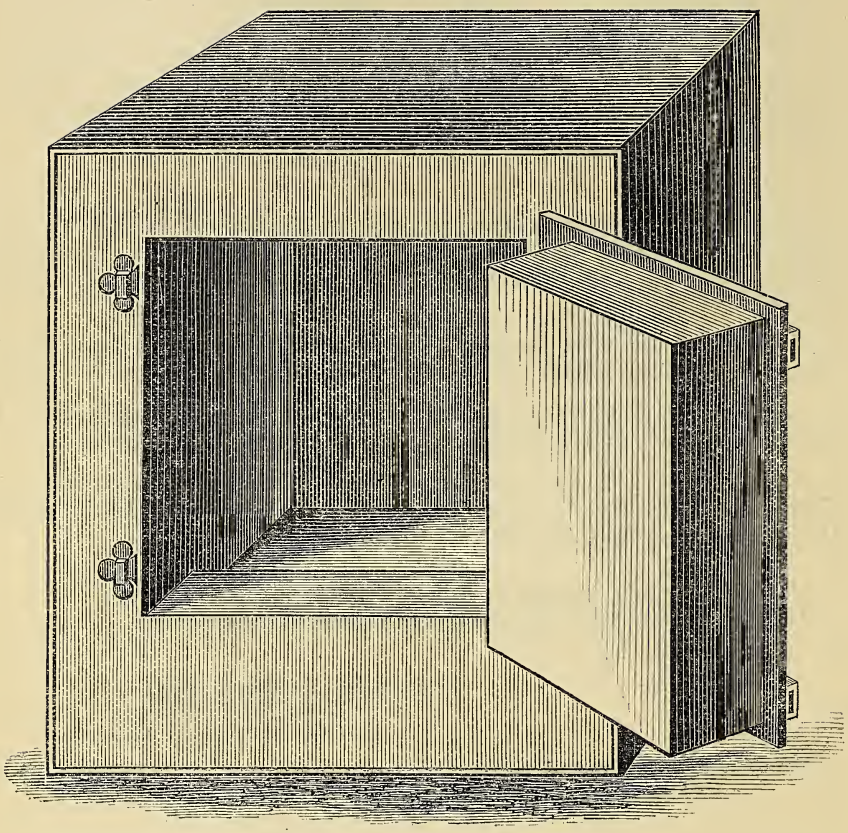
N.B.—*Visitors are earnestly requested not to attempt to approach the magazines during the progress of the experiments.*

C.

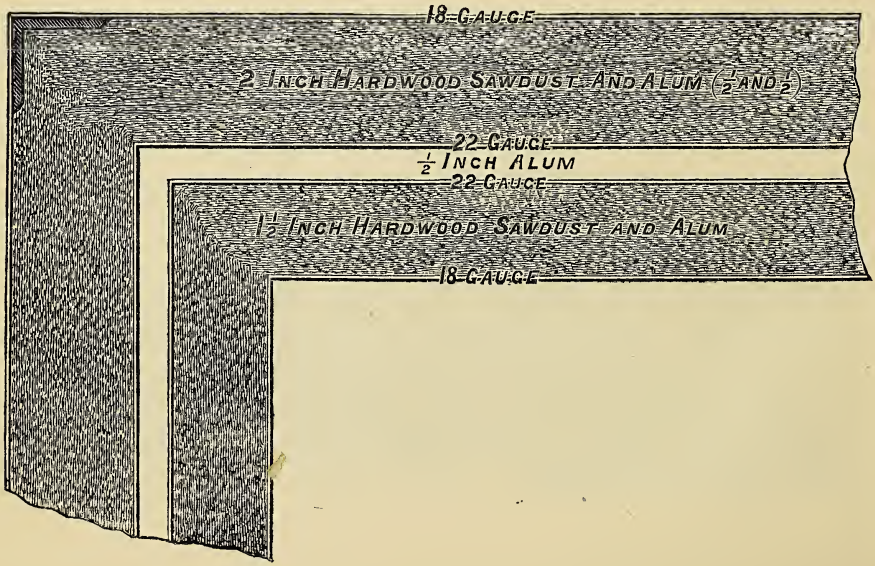
SPECIFICATION OF GUNPOWDER MAGAZINES, AS TESTED AT WOOLWICH, OCTOBER 9TH AND 10TH, 1872.

Body strongly constructed of 18 and 22 gauge charcoal sheet-iron, secured at corners with $1\frac{1}{4} \times \frac{3}{16}$ angle-iron, the chambers being filled in the following manner:—First, or inner chamber, $1\frac{1}{2}$ ins. of hard wood sawdust and alum in equal proportions; second, or centre chamber, $\frac{1}{2}$ in. alum; third, or outer chamber, 2 ins. of hard wood sawdust and alum in equal proportions, making 4 ins. thick in all. Door of magazine hung on strong wrought-iron hinges, and secured with spring latch and sliding bolts; the chambers being filled in the same manner as the body, but with an additional inner chamber of $\frac{1}{2}$ in. alum, making chambers $4\frac{1}{2}$ ins. thick. (See sectional drawings.)

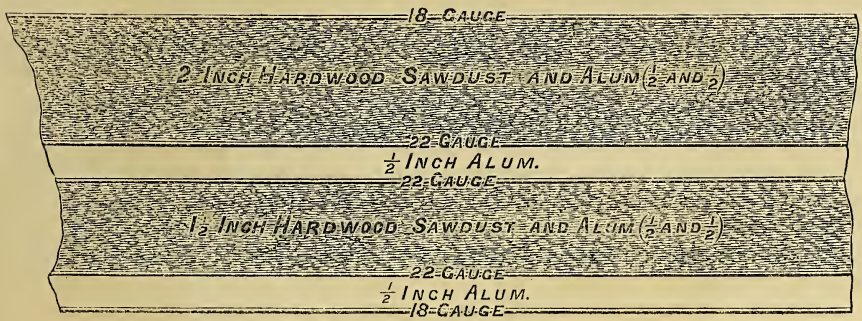
D1.



D2.


18-GAUGE
2 INCH HARDWOOD SAWDUST AND ALUM (½ AND ½)
22-GAUGE
½ INCH ALUM
22-GAUGE
1½ INCH HARDWOOD SAWDUST AND ALUM
18-GAUGE

D3.



E.

COMPOSITION OF ALLOYS OF TIN AND LEAD, WITH MELTING POINT OF EACH, ACCORDING TO A TABLE SUPPLIED BY PROFESSOR ABEL, F.R.S.

Tin. Parts.	Lead. Parts.	Melting Pt. Degs. Fahr.	Tin. Parts.	Lead. Parts.	Melting Pt. Degs. Fahr.
2	1	340	4	9	460
9	4	344	4	12	482
10	4	348	4	15	494
11	4	352	4	17	502
12	4	356	4	20	512
13	4	360	4	25	520
17	4	370	4	30	530
22	4	380	4	38	540
4	5	390	4	40	550
4	6	412	4	70	558
4	7	420			

F.

MEMORANDUM OF RESULTS OF EXAMINATION OF SAMPLES OF GUNPOWDER, AFTER REMOVAL FROM MESSRS. MILNER'S FIRE-PROOF GUNPOWDER MAGAZINES.

1. Powder canister, the contents of which had escaped ignition upon the explosion of No. 2 magazine—9 out of the 10 canisters stored in this magazine having exploded.

The powder in this canister was quite unchanged, with the exception of about 2 ozs. nearest the mouth of the canister. Moisture had penetrated to this part, and the grains had become soft and caked together.

2. Four canisters from No. 4 magazine—which had not exploded. In two of these, the powder was quite unaltered; in a third, about 2 ozs. of the powder, near

the mouth of the canister, had become damp; and in the fourth, the powder was caked together and injured by the penetration of moisture, to the extent of about one-third of the entire quantity.

3. Open keg containing 5 lbs. of loose powder. The surface of the powder had become coated with a crust, consisting of agglutinated grains, which had become friable; the crust was browner in appearance than the remainder of the powder.

The portions of powder which were in contact with the sides of the keg had become similarly agglutinated. Upon removal of the crust and careful separation of the grains which adhered loosely to it and to each other for some little distance beneath, the agglutinated portions were found to be from $\frac{1}{16}$th to $\frac{1}{8}$th in. in thickness. The grains immediately beneath were found to be unaltered in composition, but the crust itself had sustained a slight loss of sulphur, as the following analytical results show:—

	Composition of unaltered powder grains.	Composition of the crust.
	Per cent.	Per cent.
Saltpetre	75·63	75·79
Sulphur	9·95	9·48
Charcoal	14·42	14·73
Water	1·32	1·29

It is probable that in the first instance a slight absorption of moisture took place by the portions of powder to which the aqueous vapour would have more immediate access, but that the temperature of the external portions becoming in time raised somewhat above 212° (the thermometer had registered 250°), the sulphur had eventually commenced to volatilise very slowly.

The appearance of the crust did not indicate that the grains had been to any considerable extent penetrated by moisture.

The agglutination of the grains was no doubt partly due to the action of the heat upon the sulphur, and to some extent also to the slight impregnation with, and the subsequent expulsion of moisture.

(Signed) F. A. ABEL.

October 19, 1872.

THE

ACTION OF DISCHARGE UPON A FIELD GUN-CARRIAGE,

AS ILLUSTRATED BY

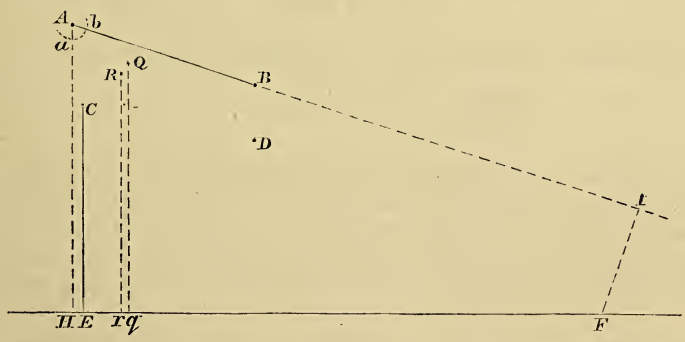
THE 16-PR. M.L.R. GUN OF 12 CWT.

BY

CAPTAIN W. KEMMIS, R.A.

If a 16-pr. gun-carriage of the latest construction be unlimbered upon level ground, and the length of the body of the axle (49″·5) be taken as the distance between the wheels, or supporting points, the statical breaking weight of the box-girder axletree-bed, applied in a vertical direction midway between the supports, will be found, by calculation in the usual way, to be 23·22 tons.

Assuming 30° (which there is no doubt is under the mark) to be the elevation at which the gun is fired when the limit of 23·22 tons vertical pressure upon the axletree and bed is reached, a few deductions as to the statical strains upon the carriage may be made. In doing so, for sake of simplicity, the forces called into action upon discharge will be taken as acting in one plane—namely, the vertical plane through the longitudinal axis of the gun; in fact, any strain due to the twist of the rifling, being comparatively small,* will be neglected.



* In severe trials, this strain makes itself evident by the right capsquare giving way, and also the right socket supporting the elevating-screw box.

In the figure, AB represents the line of the axis of the bore (making an angle of 18° with the horizontal), A being its intersection with the axis of the trunnions, and B with the axis of the bolt attaching the elevating-screw; C represents the axis of the axletree-arms at the shoulders, D that of the trunnions at the elevating-screw box, E and F the bearings of the carriage upon the ground—*i.e.*, respectively of the wheels and trail.

Let P = the maximum pressure exerted on discharge upon the carriage, applied to it at A,* and acting in the direction of the axis of the gun,

P^Y = the vertical component of P,

P^X = the horizontal component of P,

R = the maximum vertical resistance of the axle and its bed, = 23·22 tons,

W = the weight of the gun and carriage (without wheels), acting at their common centre of gravity Q, = 20 cwt.,

W' = the weight of the gun and carriage (with wheels), acting at their common centre of gravity R, = 24 cwt. 1 qr. 24 lbs.

Then, AH, CE, Rr, Qq,† being drawn perpendicular to the ground line,

$$R \times EF = P^Y \times HF + W \times qF;$$

$$\therefore\ P^Y = \frac{R \times EF - W \times qF}{HF}$$

$$= \frac{23{\cdot}22 \times 77{\cdot}25 - 1{\cdot}0 \times 70{\cdot}85}{78{\cdot}75}$$

$$= 21{\cdot}87 \text{ tons,}$$

$$\text{and } P = \frac{P^Y}{\sin 30^\circ}$$

$$= \frac{21{\cdot}87}{{\cdot}5}$$

$$= 43{\cdot}74 \text{ tons;}$$

or, per square inch of area of cross section of the bore,

$$\frac{43{\cdot}74}{10{\cdot}178} = 4{\cdot}297 \text{ tons.}$$

This being the maximum pressure transmitted to the carriage, if the maximum pressure exerted in the bore of the gun upon discharge be, as is said, 14 tons per square inch, there remains a balance between the two of 9·703 tons per square inch as the maximum force expended upon the metal of the gun. It may, however, be objected that 4·297

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* The absolute point of application is at first at a—the lowest point of the trunnion bearing—from which it is immediately changed along the bearing towards b.

† These lines are respectively 43″·25, 31″·0, 36″·0, and 37″·1 in length.

and 14 tons are really rather the expressions of blows than of pressures proper, and therefore that they are not strictly comparable; from which it follows that the balance between them of 9·703 tons may not be quite just.

The greatest elevation permitted by the form of the carriage to the gun is 18°. When the gun is fired at this elevation, the effect of the force transmitted to the carriage ($P = 43{\cdot}74$ tons) will be as follows:—

$$\begin{aligned} P^Y &= P \times \sin 18^\circ \\ &= 43{\cdot}74 \times {\cdot}309 \\ &= 13{\cdot}515 \text{ tons,} \\ P^X &= P \times \cos 18^\circ \\ &= 43{\cdot}74 \times {\cdot}951 \\ &= 41{\cdot}596 \text{ tons.} \end{aligned}$$

Also, P has a moment with respect to the point $F = P \times FI = 43{\cdot}74$ tons $\times$ 16″·6, which comes as a twist upon the bracket sides of the carriage, tending to bend them and tear them away from the second transom. This moment is opposite in direction to the moment, about the same point, of the weight of the carriage, with wheels and gun, acting at R, and $= W' \times rF = 1{\cdot}335$ tons $\times$ 72″·05. When, therefore, the first twist comes into play, it is opposed by the second, the resultant of both being a moment of 37·95 tons $\times$ 16″·6 that is acting in the same direction as P, and with the same arm. This resultant makes itself apparent on discharge by the "jump" of the gun, which in effect increases the elevation of the latter beyond that shewn by the tangent scale, and consequently affects the range of the projectile. To reduce the jump to a minimum, it is evident that in the construction of a carriage the main point is to keep the axis of the trunnions at as small a height from the ground as possible.

In addition to the small constant pressure upon the head of the elevating screw, from the centre of gravity of the gun being 0″·15 to the rear of the axis of the trunnions, there is a pressure upon it on discharge, due to the moment of the force P about the lower points of the trunnion-holes, upon which points the trunnions, having certain play in the holes, rested previous to the gun being fired. This moment equals 43·74 tons $\times$ 2″, which, the screw being at a perpendicular distance of 28″ from the bearing points, exerts a pressure upon it of 3·124 tons, which is transmitted to and expended upon the trail.

The statical breaking weight of the wooden bed first tried in the 16-pr. gun-carriage, under the same conditions as before, was 8·966 tons, and of the axletree used with it 4·164 tons, giving a total breaking weight for the bed and axle of 13·13 tons.

The gun and its charge not having been altered, the force P transmitted to this carriage was the same as to the latest pattern carriage—namely, 43·74 tons.

From these data (R and P) the angle of elevation at which the gun

is fired when the limiting value of R is reached and the axle and bed break, can be deduced, thus:—

$$R \times EF = P^Y \times HF + W \times qF,$$

$$\therefore\ P^Y = \frac{R \times EF - W \times qF}{HF}$$

$$= \frac{13{\cdot}13 \times 77{\cdot}5 - 1{\cdot}0076 \times 70{\cdot}4^*}{78{\cdot}75}$$

$$= 11{\cdot}98 \text{ tons.}$$

$$\text{But } P = \frac{P^Y}{\sin \text{ of } \angle \text{ of elevation}},$$

$$\therefore\ \sin \text{ of } \angle \text{ of elevation} = \frac{11{\cdot}98}{43{\cdot}74}$$

$$= {\cdot}27396;$$

$$\therefore\ \angle \text{ of elevation} = 15^\circ\ 54'.$$

Now, in carriages of this construction, as a fact, the axletree and bed would not stand the gun being fired at so high an elevation. To reduce, therefore, the calculated angle, either the value of P^Y—or, what is the same thing, of R—must be diminished, or that of P increased. The latter is inadmissible; for it would amount to saying that a carriage of the latest construction would not stand when the gun was fired at an elevation of 30°, which elevation, as before said, is really under the mark. It therefore remains that the value of P^Y—or rather of R, from which it is obtained—is too high; and this, no doubt, is the true case. In fact, it is not fair to take the total strength of the axletree and bed combined as the sum of their separate strength; for the elasticity of the wooden bed is greater than that of its iron axle, and consequently the latter is broken before the full strength of the former has come into play.

June, 1874.

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* The weight and distances vary slightly from those of the latest pattern carriage.

CURVED FIRE.

BY

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1. Curved Fire in General.

Curved fire is employed when the object to be struck is so secured against direct fire by an intervening covering mass that the projectile has to pass clear over the latter in order to hit the former. If the covering mass lies nearer the object than the gun we shall have, according to the end to be attained, the following kinds of curved fire:—

(*a*) *Curved breaching fire;* the aim of which is to cut out one horizontal and two or more vertical cannelures in a scarp in order to bring it down, and with it the mass of earth behind it, and in this way to produce a practicable entrance into the interior of the work.

(*b*) *Curved demolition fire;* in which there is no attempt to form regular cuts, the breaching being effected by repeated blows distributed over the face of the scarp that has to be battered. This kind of fire is employed to destroy detached walls and masonry embrasures, and to render untenable *reduits* and other casemated works.

(*c*) *Curved enfilade fire;* the object of which is to bombard either whole fronts or individual faces in the direction of their length, in such a manner that guns and troops placed behind the parapets and traverses may be struck, and the traverses and rampart damaged.

If the cover be nearer the gun than the object of fire we shall have —according as the gun belongs to the defence or the attack—

(*a*) *Curved defensive fire;* in which guns placed in low-lying casemates, or otherwise protected, fire over a covering rampart in their front at a fixed point in the open, and

(*b*) *Curved dismounting fire;* which is employed when a dismounting battery has to strike an object, firing over a protecting mass close to its own front.

In all these cases, in order that a satisfactory effect may be produced, it is most important that the object be struck with the greatest possible force. This will only be the case when the projectile just clears the top of the covering mass. Consequently, in curved fire, the path of the trajectory must be made to pass, not only through the muzzle of the gun and the object to be struck, but also through a third point—namely, the highest point of the crest to be fired over.

In enfilading a rampart by means of curved fire, the flatter the path of the projectiles, and the greater their final velocity, the better will be the effect produced. With a low final velocity and a high angle of descent (over 22°) most of the shells lodge, and have therefore no effect at all on *matériel* placed on the terreplein, unless they happen to strike it directly, and very little on the troops on duty, since the greater part of the splinters remain in the ground.

In bombarding a vertical object capable of resistance (such as masonry) by means of curved breaching and demolition fire, the employment of the largest allowable charge of powder is, however, much more important; because, with small charges, the final velocity, and consequently the depth of penetration of the projectile, is too small, and the bursting effect is thereby lessened. Moreover, at a given range, the vertical spread is considerably greater with small than with large charges.

In the case of vertical objects capable of resistance, not only the angle of descent but also the angle of impact (measured horizontally) is of importance. Elongated projectiles fired from rifled guns against strong scarp walls easily glance off if the angle of impact is less than 60°. It is only when the same place is repeatedly struck, and that with a sufficient final velocity, that the projectiles penetrate at a smaller angle of impact—say down to about 30°.

The limits within which penetration is possible, and the depth of the penetration, depend, not only on the resulting final velocity (in other words on the charge employed), but also on the nature of the object fired at.

In the experiments at Silberberg in 1869—when the short 15 c.m. gun was fired against very strong masonry in an oblique direction, the line of fire meeting the scarp at an angle of $57\frac{1}{2}°$ with a final velocity of about 176^{m}—the depth of penetration proved too slight to allow the bursting effect of the shells to be appreciated.*

At Strasburg, in 1870, the line of fire of Battery No. 8—which was armed with short 15 c.m. guns—made an angle of 55° with the

* Witte. Artillerie-Lehre. III Theil, pag. 189.

right face of Lunette No. 53 which had to be breached. This was so much the more unfavourable because at the distance of 750 metres only a small charge could be used. The masonry consisted of red sandstone, and had a thickness of 1·25 metres at the top and 1·90 metres at the base. By making use of a mine-gallery the effect could be very closely observed, and it proved that a great number of the projectiles glanced off on striking the intact masonry. Not till after four days' firing, during which a thousand projectiles were expended, was a practicable breach produced.*

When a high angle of descent is combined with a small angle of impact it is all the more unfavourable for the penetration of the projectile.

With the object at a given distance, and with given profiles, the requisite curvature of the trajectory can only be obtained by modifying the charge of powder. Should we, however, owing to the nature of the ground and the disposition of the siege works, not be tied down to a fixed distance, the necessary angle of descent may often be obtained by increasing the distance, even when using heavier charges. In the latter case we should also obtain greater final velocities within that distance at which, in general, curved breaching fire might be attempted with a prospect of success. If, therefore, the greater distance admits of the employment of heavier charges, we should give this combination the preference, provided we do not thereby sacrifice to any great extent the probability of hitting, and provided the power of resistance of the scarp to be breached appears to render desirable a greater final velocity.

With horizontal objects of fire (as in enfilading), it must be borne in mind that though the *longitudinal spread* (*Längenstreuung*) increases very nearly in proportion to the distance, still with all charges it is nearly equal for equal ranges. Should, therefore, in the case of terre-pleins insufficiently provided with traverses, the objects of fire be of sufficient longitudinal extent, an increase to the distance, by allowing of the employment of large charges, will be an advantage in enfilading. With lines well furnished with traverses it is different; and in this case it is not allowable to fix on a greater distance unless the minimum charge fails to give the requisite angle of descent.

With smooth-bore guns curved fire was only used for ricochet purposes, and curved breaching and demolition fire was only employed incidentally on real service (Alessandria, 1799, and Hüningen, 1814).

Both in England and Prussia experiments on the subject were carried out, but the Austrian artillery had paid no attention whatever to the last-named kind of fire. As, however, by the introduction of breech-loading rifled guns, curved breaching fire attained increased importance, similar experiments were undertaken in Austria in the year 1861 at Rothenneusiedel, and in 1862 at Verona, and have since then been practised to a large extent by the artillery against fixed objects. The Prussian artillery, by the experiments at Schweidnitz in 1857, at Jülich in 1860, and again at Stettin and Silberberg in

* Decker, Mittheilungen über die Anwendung des indirecten Schusses, &c.

1869, gained very valuable experience in curved breaching fire which bore fruit at the siege of Strasburg, and which, more recently, has been enlarged by the experiments at Graudenz in 1873.

The French artillery, too, in the year 1863, carried out experiments in curved fire against Fort Liédot in the island of Aix.

Though the results obtained at the above-mentioned siege corresponded to the expectations entertained, still it should not escape notice that in this case the circumstances attending the employment of this kind of fire, especially as regarded the nature of the profiles, were peculiarly favourable. In the case of the more modern fortresses —which have been planned, defiladed, and furnished with traverses with due regard to the peculiarities of breech-loading rifled guns—the employment of curved fire will be attended with far greater difficulty.

2. Ascertaining the Angle of Descent.

Supposing the covering mass to be nearer the object than the gun, if we imagine a parabola to be drawn through the following three points, viz. the centre of the muzzle of the gun, the highest point of the cover, and the point to be struck, it is evident that the small portion of this parabola which lies between the cover and the object of fire will very nearly coincide with the actual path of the shot through these points, and that, consequently, we shall be in a position to calculate the angle of descent, either at the top of the cover or at the point to be struck, by the properties of the parabola. If one of these angles and the range are known we can get the charge and elevation from the accompanying practice tables, either directly or by interpolation.

The formulas to be employed in the determination of these angles of descent, the derivation of which is given in Section 4, Part 1, of the "Handbook for the I.R. Artillery," are :—

For calculating the angle of descent at the highest point of the cover (Fig. 1),

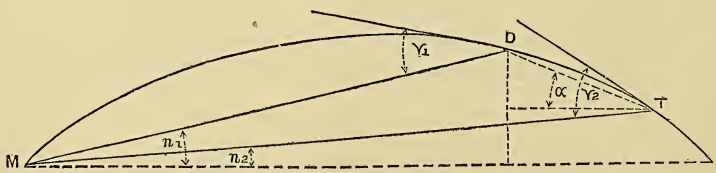
$$\tan \gamma_1 = \tan \alpha + \tan n_2, \quad \ldots\ldots\ldots\ldots (1)$$

and for calculating the angle of descent at the point of impact,

$$\tan \gamma_2 = \tan \alpha + \tan n_1; \quad \ldots\ldots\ldots\ldots (2)$$

in which the angles of descent are always measured from the line connecting the centre of the gun-muzzle and the point to be struck—in formula (1) from the line *MD*, in formula (2) from the line *MT*.

Fig. 1.



In both formulas,

$$\tan \alpha = \frac{y_1 - y_2}{x_2 - x_1},$$

if both the points D and T lie above the horizontal plane passing through M. If T lies below it we have

$$\tan \alpha = \frac{y_1 + y_2}{x_2 - x_1}.$$

In the rarely-occurring case in which both points lie below this plane we shall have

$$\tan \alpha = \frac{y_2 - y_1}{x_2 - x_1}.$$

Lastly, should it happen that the point of impact T lay in this plane, we should have $y_1 = o$, and

$$\tan \alpha = \frac{y_1}{x_2 - x_1}.$$

In the above the values of y_1 and y_2 are always taken with reference to the horizontal plane through the muzzle of the gun.

In all these cases, the numerator $(y_1 \mp y_2)$ of the fraction is invariably the difference in height of the two points; the denominator, on the contrary $(x_2 - x_1)$, their horizontal distance. If we call the first u and the last a, we shall have

$$\tan \alpha = \frac{u}{a};$$

in which expression it is all the same whether the points D and T lie above or below the horizontal plane through muzzle of the gun.

The requisite data for the calculation of the angle of descent must either be taken from such plans as are forthcoming or be determined approximately by reconnaissances and suitable combinations. The heights indicated in plans of fortifications are always referable to an assumed plane of comparison. If a plan is available there will be no difficulty in fixing the difference in height (u) between the top of the cover and the point of impact, as also the horizontal distance (a) between these points.* The measurements u and a, expressed *in similar terms* and divided one by the other, give the tangent of the angle α.

The considerations which are decisive in determining the point of impact will be discussed in parts 4, 5, and 6.

The distance of the top of the cover and its height above the gun's muzzle (in other words, the ground† angle, n_1, of the top of the cover), if not already known, can be measured by means of practical geometry. These two data will be, in general, the only available sources of information; the others which are still required for the com-

* If the line of fire is not perpendicular to the line of the protecting crest, the distance of the above-mentioned points must either be calculated, or be inferred from a bird's-eye view.

† *Terrainwinkel.* To avoid confusion of terms I have translated this word "ground angle" instead of "angle of elevation."—Tr.

putation must be partly taken from the plans, partly ascertained by reconnaissance or calculation.

Thus, if the distance x_1 be ascertained by measuring, we have

$$x_2 = x_1 + a.$$

If, by the help of the gun and a quadrant, or by an instrument for measuring angles, the ground angle n_1 of the top of the covering mass is ascertained, we shall have

$$y_1 = x_1 \tan n_1,$$
$$\text{and } y_2 = y_1 - u = x_1 \tan n_1 - u.$$

According as the difference $y_1 - u$ happens to be positive or negative we shall have, in formula (1), to account $\tan n_2 = \frac{y_2}{x_2}$ positive or negative. Some examples further on will illustrate this.

It is a matter of indifference which of the two formulas is employed; but it must not be overlooked that the first gives the angle of descent for the distance x_1, the second that for the distance x_2 $(= x_1 + a)$, and that the elevation, which has to be taken from the practice tables, will have to be corrected accordingly, as directed in part 7.

If the angles n_1 and n_2 are very small we can substitute the angles themselves for their tangents.

For instance, if the portion DT (Fig. 1) of the trajectory is considered as part of a circular arc drawn through the points M, D, T, we shall have (as was shown in Section 4 Part 1 of the "Handbook for the I.R. Artillery"),

$$\gamma_1 = \alpha + n_2,$$
$$\text{and } \gamma_2 = \alpha + n_1;$$

which formula can easily be deduced from the properties of the circle in accordance with the principles of geometry.

In practice it is of little consequence whether the angles or their tangents are taken.

3. Influence of the Nature of the Profiles.

If the ground is nearly level the values of n_1 and n_2 are very small and have slight effect on the magnitude of the angle of descent. If the objects of fire are of any considerable height the angles of descent are less favourable, because the ground angles n_1 and n_2 are then positive and increase with the height of the cover and of the point of impact. Therefore, for curved fire, low-lying gun sites are less favourable than elevated ones, although at the longer ranges a small difference in height in the position of the battery is of no material importance. Thus, for instance, at 1000 metres a difference in height of 1^m in the position of the gun gives a difference of ground angle of only $3\frac{1}{2}'$.

With curved fire the necessary angle of descent depends, therefore, essentially on the quotient $\frac{u}{a}$ $(= \tan \alpha ab)$. The greater the distance a

of the top of the cover from the point of impact, and the less the difference of height of these two points, the smaller will be $\frac{u}{a}$, and the flatter the requisite angle of descent.

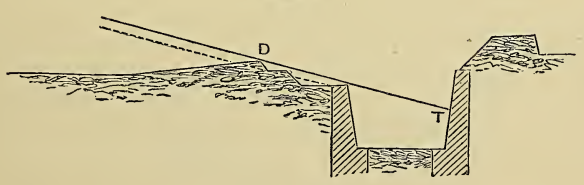
Now, in order to keep the distance a as large as possible, we must endeavour, in curved breaching and demolition fire, to take the scarps in lines down the ditches, not across them. We shall in this way obtain flat angles of descent when firing at the escarps, the flanks, the caponnières opposite the centres of the sides of the polygon, those parts of the bastion faces that can be struck through the ditches of the ravelins, the redoubts in the covered way if they can be taken in the direction of its branches, &c., &c. In the case of the older fortresses, it will, however, often happen that the distance a is sufficiently great to give a flat angle of descent.

The artifice of increasing the distance a by adopting an oblique line of fire, is, in the case of breaching and demolition fire against strong masonry, of little use; because what is gained, as regards striking force, by reducing the angle of descent (in other words, by increasing the charge) is lost by the projectile striking obliquely. We therefore, in general, only make choice of an oblique position if other local circumstances render it necessary.

Finally, in order to reduce the value of the quotient $\frac{u}{a}$, it is important that the difference in height of the top of the cover and point of impact should be kept as small as possible. With given profiles this partly depends on how the point of impact is chosen. This will be fully discussed further on; for the present we will simply allude to the means by which the profile conditions may be altered—viz., by knocking away the top of the covering mass, and by employing mines to partially remove it.

It is only under exceptional circumstances that the height of the cover can be reduced more than 1 or 1·5 metres by knocking away its crest, even when 15 c.m. shells $2\frac{1}{2}$ calibres in length and heavy bursting charges are employed. It is, moreover, not always possible to attain a lower point of impact by knocking away the crest of the glacis, as may be seen by Fig. 2.

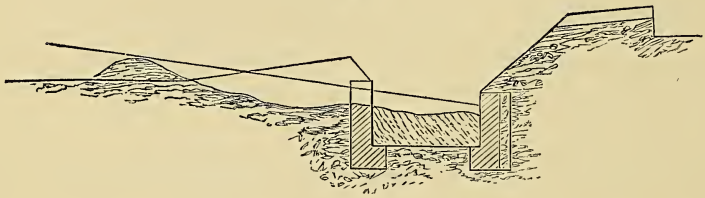
Fig. 2.



Should the profile of the work that is to be breached necessitate an angle of descent which cannot be attained at that distance which, as regards probability of hitting and final velocity, is such as gives promise of sufficient effect, we must have recourse to overcharged

mines in order to throw down the revetted counterscarp. Should this give us then a formation such as is shown in Fig. 3, the altered profiles will admit of the advantageous employment of curved breaching and demolition fire from greater distances. This is to be preferred to direct breaching, because we can better secure ourselves against the splinters which fly back,* and against the musketry fire of the defenders; and, generally, the establishment of direct batteries on the crowning of the covered way is attended with great sacrifices.

Fig. 3.



Direct breaching fire from the crowning of the covered way is, moreover, impracticable when, owing to the narrowness of the ditches and the masonry counterscarp, the escarp cannot be taken deep enough.

4. Choice of the Point of Impact in Curved Breaching Fire.

From the experience gained at Jülich the method usually pursued in the case of direct breaching fire from smooth-bore guns—which consists in cutting out a portion of the masonry by means of a horizontal cannelure and of a vertical one at each of its ends—has been judged as advantageous for curved breaching fire also.

The height at which the horizontal cannelure should be placed, and which—as in the case of direct breaching fire—depends on the profile of the rampart to be breached, was taken, in the case of ordinary shells and very strong profiles difficult to breach, at one-third the height of the scarp. According to later experience, with 15 c.m. shells $2\frac{1}{2}$ calibres in length it may be placed at *half* that height; because, owing to the greater bursting effect of these projectiles, the scarp gets shattered to a much greater depth below the cut.

It is evident that if we base the calculation of the angle of descent, and consequently the determination of the charge and elevation, on a given point of impact at a fixed height, and make use of this charge and elevation, at least half the shots will be thrown away, because the lower half of the set or sheaf of trajectories (*Flugbahngarbe*) will be intercepted by the covering mass, and consequently no shot can strike *below this point*. But if, however, we wish to group as many shots as possible

* Shell splinters and stones are generally thrown back as far as 150 metres; a few larger stones —some kilogrammes in weight—fly back more than 200 metres; and the bottoms of the shells as far as 450 metres. (Prussian experiments with the short 15 c.m.)

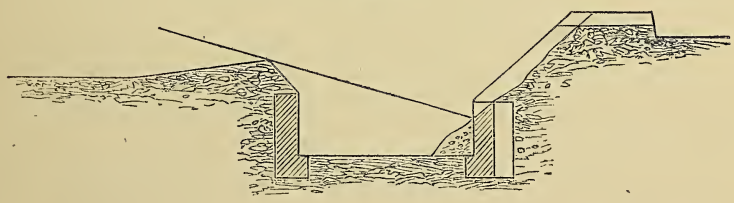
about this selected point of impact (taken at a fixed height), the calculation of the angle of descent must be made with reference to a point below it. If we wish to utilise half, at least, of the projectiles in the lower half of the trajectory pencil for the purpose of breaching, the *lowest* point in fixing the angle of descent must be taken lower by half the 50 per cent. vertical spread (*Höhenstreuung*); because for this point the chances are even that those projectiles will strike the scarp. If the charge and elevation have been determined for this point it is self-evident that the trajectory must be raised by just half this 50 per cent. vertical spread. If, then, this process is carefully conducted, and conditions in other respects are normal, the resulting mean point of impact will coincide with the intended one.

If it is intended to make the horizontal cut at half the height of the scarp the lowest point of impact must be half the 50 per cent. vertical spread below it. Should, however, the vertical spread for the charge to be employed be but slight, and the profile conditions admit of an expectation that the masses of earth above the scarp will come down in sufficient quantity to produce a practicable breach, the *lowest* point of impact may be fixed at half the height of the escarp, the angle of descent calculated for this height, the charge and elevation found, and the latter then increased as much as may be necessary to raise the mean point of impact by half the 50 per cent. vertical spread. Should, however, half the vertical spread be greater than the half height of the strikeable surface, it will be advisable to fix the mean point of impact at half the height of the latter, because otherwise a considerable number of shots would pass over the mark.

Finally, should the profile conditions be very unfavourable, the vertical spread considerable, and the resulting final velocity insufficient; further, should the latter not admit of an increase by increasing the range, owing to this entailing other drawbacks, there will be nothing gained by raising the trajectory, and we must leave it to the projectiles that fall short to cut away part of the crest of the covering mass. If this is done to a sufficient extent the succeeding shots will bring the mean point of impact to a lower level.

With profiles like the one represented in Fig. 4 the mean point of impact may, from the very first, be taken at a little above half the height of the scarp.

Fig. 4.



Since in indirect breaching by means of regular cuts the scarp has to be struck in certain horizontal and vertical lines, it follows that in this kind of fire a certain degree of probability of hitting is indis-

pensable; and therefore, as a rule, heavy charges combined with short ranges are the most useful. Should it not be possible to combine both, then a greater initial velocity, and consequently a greater distance, is to be preferred, even though the probability of hitting may not be all that could be desired. This is, however, only possible when we are not tied down to any particular spot in selecting the position of the gun.

Lastly, in choosing the lowest point of impact, it has further to be taken into consideration that with large angles of descent it may be fixed somewhat higher; because, according to all experience, the horizontal cut always gets widened downwards in proportion to the depth the projectiles penetrate the scarp, especially when breaching with 15 c.m. shells $2\frac{1}{2}$ calibres long—these shells having almost twice as great a bursting effect as the ordinary ones. At an experiment at Silberberg with the short 15 c.m. gun (angle of descent 6°, final velocity 175 metres), the mean point of impact got lowered by 0·4 metre by the time the scarp had been quite broken through. It may be taken for granted that, *cæteris paribus*, this would have been the case in a greater degree with a higher angle of descent.

5. Choice of the Point of Impact in Curved Demolition Fire.

Curved demolition fire is employed against raised buildings, caponnières, *reduits*, and detached walls of every kind.

The method of proceeding, when a certain line of embrasures has to be struck, is the same as in producing a horizontal cut. The intended point of impact lies, in this case, in the line of embrasure roofs. The proper weight of the charge will be calculated from the angle of descent for this line and from the range. In the practice tables are to be found the 50 per cent. vertical spread for this charge and for the given distance. The lowest point will be taken at half this vertical spread below the line of embrasure roofs, and the angle of descent for it calculated exactly.

Very frequently the profile conditions will be so unfavourable that only small charges and high angles of descent can be employed, and the probability of hitting will consequently be slight. In the case, however, of small *reduits* with but little strength of scarp, which a little battering would render untenable, a systematic destruction of the rows of embrasures may be dispensed with.

To produce a breach in a detached wall, or to bring it down, comparatively few blows, distributed over the face that has to be battered, are sufficient. The greatest probability of hitting would be obtained if the lowest point of impact were taken at the foot of the wall, and the point aimed at at half its height. In the case, however, of fortifications planned with tolerable judgment, walls of this nature are protected within a certain angle of descent. It has therefore to be ascertained how low down the lowest point of impact can be taken, and the mean point of impact then placed at the centre of the *strikeable* surface. If the lowest point of impact be too high

a practicable breach will not be produced. If the strikeable surface is too small only slight results can, in general, be expected. Thus, in demolition fire too, all the circumstances of the case have to be taken into consideration. If we are not tied down to a particular distance we can the better take into account the object to be attained and the nature of the target in fixing the charge and elevation. In doing this it should always be remembered that heavy charges (by giving a high final velocity) are the most advantageous, because the projectiles then penetrate deeper and the bursting effect is greater.

Since, in the case of demolition fire, the effect does not depend on the cutting out of a fixed line, it can be undertaken at greater distances if the strikeable surface is large enough. It can even occasionally be carried on by the batteries of the first period; because it is important to destroy, as soon as possible, the defensible barracks, flanking batteries, and, in general, secure shelter of every kind.

6. Choice of the Point of Impact in Enfilade Fire.

The process of arming the works and placing them in a state of defence has, in general, to be hindered by means of enfilade fire from the batteries of the first period, established at considerable distances from the objects of fire. In this case the full service charge can, as a rule, be employed; the trajectory, owing to the long range, possessing already sufficient curvature.

Reduced charges are only to be employed when a protecting obstacle has to be fired over to hit a fixed point behind it. To do this the angle of descent must be calculated, according to the given conditions; and, in the case of horizontal objects of fire, for the *nearest* point of impact, just as with vertical objects the *lowest* point is taken.

In enfilading a terreplein unprovided with traverses the greatest number of hits will be obtained by taking the nearest point of impact as close as possible to the protecting crest. On the other hand, the necessity of employing the heaviest allowable charges debars the *nearest* point of impact from being taken *too* close to it.

The charge and elevation are determined for the point of impact already decided on, and the trajectory then sufficiently raised, by increasing the elevation in proportion to the range, to bring the mean point of impact to half-way between the *nearest* point of impact and the end of the terreplein. If, therefore, what has to be done is to bombard the interior of a work, and if there is no occasion to direct the fire in preference against any particular portion of it, the mean point of impact should be so selected that the hits may be uniformly distributed, and that, as regards the longitudinal and lateral spread of the projectiles, as many shots as possible may be utilised.

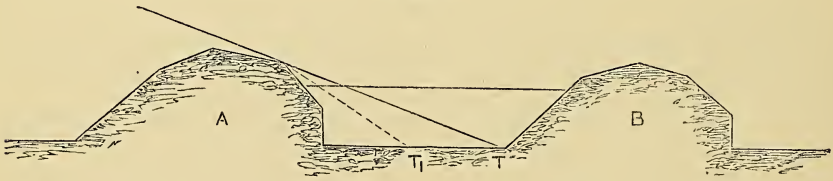
If the objects of fire have a considerable extent of surface, we should, both when enfilading lines unfurnished with traverses and when bombarding the interior of a work, direct each gun against a fixed point, so as to bring every part of the work under an equal amount of fire. Since the lateral spread of the projectiles is considerably less

than the longitudinal, and in itself not very great, it will be of advantage to shift the point of impact laterally during the course of the bombardment as circumstances may require.

Should there be traverses on the terreplein, and should there be a deficiency of information as to their height and distance apart, we must take an angle of descent of 10° to 15°, place the mean point of impact at half the length of the space between the traverses, and after this get the charge corresponding to the distance from the practice tables. If the length of the line to be bombarded amounts to more than the whole longitudinal spread—that is, to more than four times the 50 per cent. spread—we must, in the course of the bombardment, so alter the laying, both as to elevation and direction, that every part of the terreplein may be struck in its turn.

If circumstances allow accurate information to be obtained as to the situation, height, and length of the traverses, it seems advantageous to take the *nearest* (or lowest) point of impact at the foot of a traverse—as is shewn in Fig. 5—and to calculate the angle of descent accordingly.

Fig. 5.



It is evident that, with this arrangement, all the shots of the lower half of the set of trajectories will strike the traverse *A*, and all those of the upper half the traverse *B*. If, therefore, we wish to strike the terreplein, we must take the nearest point of impact, not at T, but at T_1. If now we were to make TT_1 equal to the half of the 50 per cent. longitudinal spread, we could make about 25 per cent. strike the terreplein by placing the mean point of impact at T_1, and elevating the trajectory by a corresponding amount; but this position of the *nearest* point of impact will, in general, give too steep an angle of descent, which would only allow of the employment of very small charges, and would consequently entail a very large vertical spread. Under such circumstances it is judicious, at the commencement of the bombardment, not to attempt to touch the guns of the defence with the lower half of the trajectory pencil. In proportion as the protecting traverse gets cut away by the shots that fall short will a greater number strike the terreplein.

Moreover, those shells which graze the top of a traverse and explode will exercise a very considerable effect against the troops on duty that happen to be behind the traverse. With regard to the latter, it would appear allowable in the case of very high traverses placed near each other to take the nearest or lowest point of impact about a metre above the foot of the traverse, so as to fix the charge for the smaller angles of descent that will consequently result.

A raising of the trajectory by a corresponding increase of the eleva-

tion—as may happen in the case of curved breaching or demolition fire—for the purpose of utilising a fixed per-centage of the lower half of the trajectory pencil, would, if the nearest or deepest point of impact were taken at the foot of the traverse (or one metre above it), cause a diminution of the per-centage of hits, as regards the artillery *matériel* and the *personnel* to be struck; because, in this case, the closest grouping of the enfilading shots would be at too high a level.

If the lines to be enfiladed are provided with traverses according to the principles of modern fortification the angles of descent will be so steep that in enfilading at the *shorter ranges* it will be very difficult, even with the short 15 c.m. gun and the smallest charges, to hit the guns situated behind the traverses.

At the longer ranges of 1200 to 3000 metres, the mortar-like effect of the 15 c.m. gun can, in such cases, be utilised. The guns fire thus at an angle of 25° or 30°, with a charge corresponding to the distance (as with mortars), practice tables being specially prepared for the purpose.

With such unfavourable profile conditions it even appears advisable, before commencing the enfilade fire, to cut away the crests of the traverses by a systematic bombardment, using full service charges.

In enfilade firing, in order to endanger the communications round the traverses and with the lower terreplein terraces, we should bombard this part of the terreplein by directing on it that flank gun of an enfilading battery the line of fire of which lies innermost, and take the point of impact according to the lateral spread of the piece. The employment of a larger charge will, in the case of this gun, be, in general, possible.

The fire of the remaining guns should be concentrated either on the interval between two traverses, or on that between the parapet and the first traverse; and as the bombardment proceeds the mean point of impact should be transferred to the other intervals in succession. The way in which the lateral spread of the projectiles has to be taken into consideration in the selection of the line of fire will be discussed in part 12.

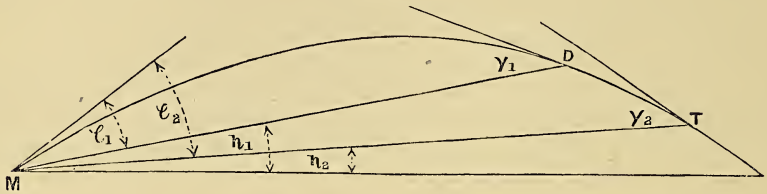
7. Determination of the Charge and Elevation when the Angle of Descent and Distance are Given.

In order to enable us to determine, with the help of the practice tables, the charge and elevation for curved fire, we must first calculate, according to the directions given in part 2, the angle of descent either for the top of the covering mass or for the lowest or nearest point of impact.

We then take from the practice tables that charge which gives this angle of descent at the given distance. If the distance is not exactly given in the tables we interpolate the angle of descent between the next smaller and the next larger distances. If the final velocity given in the tables for the charge corresponding to the angle of descent holds out an expectation of a good result with reference to the capability of resistance of the scarp, then the charge to be employed

will have been found. The angle of elevation (height of the tangent scale) and the deflection are then to be either taken directly from the other columns of the tables or interpolated between the next smaller and next larger distances.

Fig. 6.



As regards the angles of elevation, it must, however, be borne in mind that the angles of descent γ_1 and γ_2 (Fig. 6) are always reckoned from the straight lines *MD* and *MT*, and that therefore also the corresponding angles of elevation of the practice tables must likewise be reckoned from these lines, and can only be employed when the points *D* or *T* happen to lie in the same level as the muzzle of the gun. If these points lie higher, the trajectory must be raised by the ground angle of the point to be struck; if they lie lower, the trajectory must be lowered by the corresponding ground angle. Thus, if for the angle γ_1 and the distance *MD* the angle of elevation is found to be ϕ_1 the angle to be used will be $\phi_1 + n_1$.

If the angle of elevation ϕ_2 is determined from the angle γ_2 and the distance *MT* the angle $\phi_2 + n_2$ must be employed. In both cases must the same result ensue. If one of the points *D* or *T* lies below the level of the muzzle, the ground angles n_1 or n_2 are to be subtracted. A few examples will illustrate more clearly the method of proceeding to be observed:—

Ex. 1.—An escarp wall has to be breached with the short 15 c.m. breech-loading gun; but, owing to the distance of the battery from which it is to be done, systematic breaching is not contemplated. The distance of the top of the crest of the protecting glacis is 1200 metres, and the ground angle of this crest is found by measurement to be $+ 41'$. Moreover, after considering all the circumstances of the case, it has been deemed advisable to fix the *lowest* point of impact at 5·84 metres below the crest of the glacis. The horizontal distance of the point of impact from the crest is 28 metres.

We have now,

$$x_1 = 1200 \text{ metres}, \quad a = 28 \text{ metres},$$

$$x_2 = 1228 \quad " \quad n_1 = +41', \quad u = 5{\cdot}84 \text{ metres},$$

$$y_1 = 1200 \tan 41' = 14{\cdot}31 \text{ metres},$$

$$y_2 = y_1 - u = 14{\cdot}31 - 5{\cdot}84 \text{ metres} = 8{\cdot}47 \text{ metres},$$

$$\tan n_2 = \frac{8{\cdot}47}{1228} = 0{\cdot}0069, \text{ and } n_2 = 24',$$

$$\tan \alpha = \frac{u}{a} = \frac{5{\cdot}84}{28} = 0{\cdot}2087.$$

1. If formula (1) is employed, we have

$$\tan \gamma_1 = \tan \alpha + \tan n_2 = 0{\cdot}2087 + 0{\cdot}0069 = 0{\cdot}2156,$$
$$\gamma_1 = 12^\circ\ 10'.$$

In the practice tables of the short 15 c.m. breech-loading gun we find for a distance of 1200 metres and an angle of descent of 12° 10′ a charge of 0·9 kilogrammes; and as the final velocity, which is given as 164·4 metres, may be looked upon as sufficient, this charge may be employed.

In the corresponding column of this table the angle of elevation is given as 11° 25′; therefore the angle of elevation corresponding to the lowest point of impact will be 11° 25′ + 41′ = 12° 6′.

With this elevation half of the shots would strike the glacis; the vertical spread is given as 3·45 metres, and its half is therefore 1·73 metres. In the next column we find that 5′ more elevation move the point of impact 1·72 metres higher; we must therefore further increase the elevation by 5′, making it 12° 11′.

2. If formula (2) is employed, we have

$$\tan \gamma_2 = \tan \alpha + \tan n_1;\ \text{and, since } \tan 41' = 0{\cdot}0119,$$
$$\tan \gamma_2 = 0{\cdot}2087 + 0{\cdot}0119 = 0{\cdot}2206,$$
$$\gamma_2 = 11^\circ\ 27'.$$

Though the distance x_2 (= 1228 metres) is not exactly given in the tables it is still to be inferred that the required angle of descent can be obtained between 1200 and 1300 metres with a charge of 0·9 kilogrammes; and we find by interpolation,

	°	′
Angle of descent for 1300 metres =	13	22
" " 1200 " =	12	10
Difference	1	12

And since

$$100 : 28 :: 1^\circ\ 12' : x,$$
$$\text{by which } x = 0{\cdot}72 \times 28' = 20',$$

we shall have the angle of descent for 1228 metres = 12° 10′ + 20′ = 12° 30′, which is only slightly larger than the required one of 12° 27′; consequently, the charge of 0·9 k.g. is to be regarded as the correct one.

Since the elevation for 1228 metres is not given in the table, we interpolate.

	°	′
Angle of elevation for 1300 metres =	12	31
" " 1200 " =	11	25
Difference	1	6

$$100 : 28 :: 1^\circ\ 6' : x,$$
$$x = 0{\cdot}66 \times 28 = 18'.$$

The elevation for 1228 metres is consequently

$$11^\circ\ 25' + 15' = 11^\circ\ 43'.$$

This elevation has still to be increased by the ground angle $n_2 = 24'$, which gives $12^\circ\ 7'$. If now the trajectory is raised by half the 50 per cent. vertical spread, or about $5'$, the elevation becomes $12^\circ\ 12'$, which only differs by $1'$ from that obtained by formula (1).

Since the practice tables are given for charges at intervals of 100 grammes, the angles of descent necessitated by the profile proportions are not always to be found in the tables. If the difference is only slight the *next larger angle of descent should be taken,* and rather too small a charge used. Should the difference be large we must obtain the angle of descent corresponding to an intermediate charge, by taking the arithmetic mean of the angles of descent given in the practice tables for the given distance. If this mean angle is the same as the required angle of descent, or only a little larger, the mean charge should be employed. In that case the arithmetical mean of the angles of elevation for the two consecutive charges at the given distance will be the correct elevation.

Ex. 2.—The face of a work constructed on an old system has to be breached by means of curved fire from the short 15 c.m. gun. From plans, and by reconnaissances, the following particulars as to the profiles are obtainable:—The work has a ditch 20 metres wide and a covered way 10 wide, so that the crest of the glacis is 30 metres from the escarp. The glacis crest is 1 metre above, and the bottom of the ditch 7·5 metres below, the plane of comparison drawn through the cordon. If, on the first examination of the case, the lowest point is taken at half the height of the scarp, we shall have

$$\tan \alpha = \frac{3{\cdot}75 + 1}{30} = \frac{4{\cdot}75}{30} = 0{\cdot}15833;$$

which corresponds to an angle of 9°, which angle must further be increased by the ground angle; so that the necessary angle of descent may be estimated at $9\frac{1}{2}^\circ$.

A glance at the practice table shows us that this angle of descent can be obtained at a distance of between 900 and 1000 metres with a charge of between 0·8 and 0·9 kilogrammes, and that the resulting final velocity will be between 156 and 167 metres. On account of this low velocity it will not do to reduce the charge, and therefore the distance cannot be lessened; whilst an increase of the charge by increasing the distance is not advisable, owing to some steep rising ground opposite the fortress, by which the angle of descent would be considerably increased. On the other hand, an advantageous spot is found at 909 metres from the crest of the glacis, where the terrain angle (n) is only $5'$. But with the selection of this spot for placing the breaching battery is combined the drawback that the line of fire meets the face obliquely at an angle of 60°; this, however, increases the distance (a) of the crest from the escarp, and thus gives a better angle of descent. In selecting the lowest point of impact it has further to

be taken into consideration that the foot of the exterior slope of the parapet is about 1 metre from the cordon, and that, owing to the berm thus formed, the mass of earth above the escarp will not be thrown down in sufficient quantity. It therefore appears more judicious to fix the *mean* point of impact at half the height of the scarp and the *lowest* point of impact half the 50 per cent. vertical spread below it.*

As we have already estimated the charge from the magnitude of the angle α, half the 50 per cent. vertical spread for 0·8 kilogrammes at between 800 and 900 metres can be taken as 1·25 metres.

The calculation can now be made by formula (2) as follows:—

for the difference in height,

$$u = 1^{m} + 3{\cdot}75^{m} + 1{\cdot}25^{m} = 6 \text{ metres};$$

and for the horizontal distance,

$$a = \frac{30}{\cos 30^{\circ}} = \frac{30}{0{\cdot}886} = 34{\cdot}7 \text{ metres};$$

therefore

$$\tan \gamma_2 = \tan \alpha + \tan n_1 = \frac{6}{34{\cdot}7} + \tan 5' = 0{\cdot}17293 + 0{\cdot}00145 = 0{\cdot}17438,$$

$$\gamma_2 = 9^{\circ}\ 53\tfrac{1}{2}'.$$

The distance x_2 is $909^{m} + 34{\cdot}7^{m} = 943{\cdot}7^{m}$, or in whole numbers 944^{m}. The angle of descent for this distance is found by interpolation; thus we have

0·8 k.g.	0·9 k.g.
10° 37′,	9° 15′,

of which the arithmetical means are

0·85 k.g.
9° 56′.

As this angle is only slightly larger than the required angle of descent (9° 50′), the charge of 0·85 k.g., although somewhat too small, may be considered as the correct one.

If the value of γ_2 lay between 10° 37′ and 9° 56′ the charge of 0·8 k.g. would have to be used: on the other hand, for all values from 9° 56′ to 9° 15′ we should use 0·85 k.g.

To calculate the angle of elevation for 944 metres, we have, by interpolation, for

0·8 k.g.	0·9 k.g.
$\phi = 10^{\circ}\ 4'$,	$\phi = 8^{\circ}\ 45'$,

therefore, taking the arithmetic means,

for 0·85 k.g.
$\phi = 9^{\circ}\ 25'$.

* "Half the 50 per cent. vertical spread" is equivalent to the *probable* vertical deviation (either above or below the point aimed at) of any particular projectile.—Tr.

This angle is measured from the straight line connecting the centre of the gun's muzzle with the point of impact. The ground angle n_2 has therefore to be found. The crest of the glacis lies above the level of the gun's muzzle by $909^m \times \tan 5' = 1{\cdot}32$ metres. The point of impact was fixed at 6^m below the crest of the glacis; therefore

$$y_2 = 1{\cdot}32^m - 6^m = -4{\cdot}68^m,$$

$$\text{and } \tan n_2 = -\frac{4{\cdot}68}{944} = -0{\cdot}004958,$$

$$n_2 = -17',$$

and the above-mentioned angle of 9° 25′ must be diminished by 17′, giving 9° 8′ as the angle of elevation for the lowest point of impact.

Finally, to bring the *mean* point of impact to half the height of the scarp, the trajectory for 944 metres must be raised by $1{\cdot}25^m$, which can be done by an addition of about 4′. The angle of elevation to be employed is therefore 9° 12′.

We can arrange for the raising of the trajectory while determining the angle n_2, by taking the point of impact at half the height of the scarp, by which

$$y_2 = 1{\cdot}32 - 4{\cdot}75 = -3{\cdot}43,$$

$$\tan n_2 = -\frac{3{\cdot}43}{944} = -0{\cdot}003634,$$

$$n_2 = 13' \text{ (negative)},$$

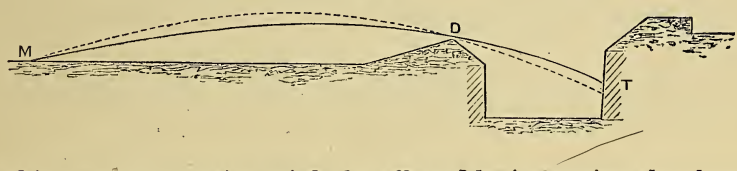
and the angle of elevation = 9° 25′ − 13′ = 9° 12′. As the quadrant does not allow angles to be measured at less intervals than 2½′, the angle of elevation must be taken at 9° 12½′.

Fig. 7.

An interpolation of this kind would be unnecessary if the practice tables were arranged for charges at intervals of 50 grammes; this, however, would make them too voluminous. Moreover, the method of proceeding which has here been given is excessively simple, correct enough for practical purposes, and (which is very important) gives in general rather too curved than too straight a path. If we were to take, in employing formula (1), the next larger charge (or the next smaller angle of descent) we should get a straighter path (Fig. 7). As the angle of elevation is calculated for the distance *MD* the trajectory would certainly pass through the point *D*, but at the same time would strike the scarp above the intended point *T*. If we were to correct this error by decreasing the elevation the shots would impinge against the cover. If the trajectory is raised for half the 50 per cent.

vertical spread the point of impact will be so much the higher, and if a correction is made for this the cover will be again struck; there is therefore no alternative but to reduce the charge. If, on the contrary, rather too small a charge has been chosen (and therefore a larger angle of descent), the trajectory will again pass through the point *D*, and, in consequence of its greater curvature, will strike below the point *T* (Fig. 8).

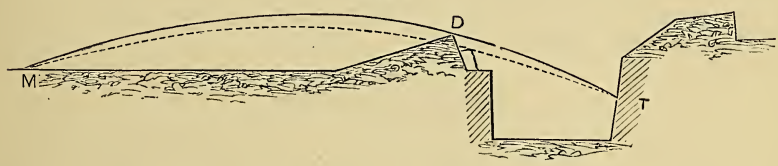
Fig 8.



In this case a correction might be effected by increasing the elevation.

The result is the same if the charge and elevation are obtained by formula (2). Fig. 9 shows the consequences of too large a charge.

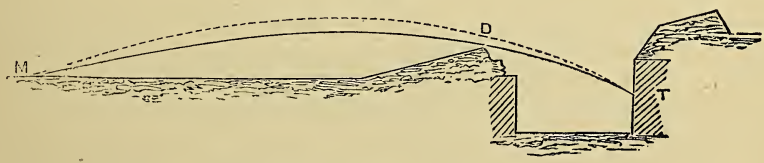
Fig. 9.



The trajectory would strike the intended point of impact, but that, owing to its flatness, the projectiles are intercepted by the screen *D*; so that, when using this formula also, too heavy a charge is disadvantageous.

If, on the other hand, the next smaller charge (and therefore the next larger angle of descent) is taken (Fig. 10), it will be possible to make small corrections by increasing, or even diminishing, the elevation.

Fig. 10.



Whether the charge and elevation be obtained by formula (1) or (2), it is always better to have the charge rather too small than too large. By the more curved path thus involved some striking power is lost, it is true, but the mark will not be overshot, and if the projectiles strike too low they can be made to hit the object of aim by increasing the elevation.

Ex. 3.—A battery armed with short 15 c.m. B.L. guns is constructed on the prolongation of the capital of a work at a distance of 850 metres

from the glacis, for the purpose of demolishing a casemated redoubt situated in the gorge. It appears from available plans, which have been verified by reconnaissance and actual observation, that the masonry of the redoubt is protected by a traverse placed at a distance of 20 metres from it. The crest of the traverse is about one metre higher than that of the glacis, and 75 metres from it; so that the total distance of the battery from the crest of the traverse is 925 metres, and from the redoubt 945 metres. Finally, the angle of elevation of the line joining the gun's muzzle and the glacis crest is ascertained to be 6′.

Since the crest of the glacis is one metre lower than that of the traverse, the ground angle of the nearest point of the latter is obtained by a simple geometrical calculation.

$$\tan n_1 = \frac{850 \tan 6' + 1}{925} = \frac{2{\cdot}4833}{925} = 0{\cdot}00268;$$

$$\text{whence } n_1 = 10', \text{ and } y_1 = 2{\cdot}4833 \text{ metres.}$$

The foot of the redoubt is 6·5 metres below the level of the top of the traverse. If we wish to take the former as the lowest point of impact we shall have

$$\tan \alpha = \frac{6{\cdot}5}{20} = 0{\cdot}325,$$

$$\text{and } \alpha = 18^\circ.$$

A glance at the practice table shows that for this angle the charge would have to be taken much too small; we therefore decide to take the lowest point of impact half-way up the scarp (which is 5·7 metres high), or $6{\cdot}5^{\text{m}} - 2{\cdot}85^{\text{m}} = 3{\cdot}65$ metres below the top of the traverse. We have, consequently, by formula (2)

$$\tan \gamma_2 = \tan \alpha + \tan n_1 = \frac{3{\cdot}65}{20} + 0{\cdot}0026 = 0{\cdot}1852,$$

$$\gamma_2 = 10^\circ\ 30'.$$

Moreover, we find in the practice tables for the charge of 0·8 k.g. that for a range of 945 metres the next larger angle of descent is 10° 38′. There can be no doubt that 0·8 k.g. is the proper charge for the case in question. The corresponding final velocity of 156 metres may also be looked upon as sufficient to effect the object in view. We now interpolate the angle of elevation for 945 metres between 900 and 1000 metres, and obtain $\phi = 10^\circ\ 5'$.

This angle would be the one to be employed if the point to be struck lay in the same horizontal plane as the muzzle of the gun. But we find that while the mid-height of the scarp is 3·65 metres *below* the top of the protecting traverse, the latter is 2·483 metres *above* the level of the gun's muzzle. Consequently the mid-height of the scarp is $3{\cdot}65 - 2{\cdot}483 = 1{\cdot}167$ metres *below* the horizontal plane in question.

We must, moreover, unless we would lose the whole effect of the projectiles of the lower half of the set of trajectories, fix the point

of impact at half the height of the strikeable portion—that is, at $\frac{3 \cdot 65}{2} = 1 \cdot 825$ metres higher. The intended point of impact will therefore be $1 \cdot 825 - 1 \cdot 167 = 0 \cdot 658$ metres above the level of the gun's muzzle, and we shall have

$$\tan n_2 = \frac{0 \cdot 658}{945} = 0 \cdot 0007.$$

Consequently $n_2 = 3'$, and, finally, the correct angle of elevation will be $10^\circ\ 8'$.

Ex. 4.—A line 80 metres in length, and without traverses, has to be enfiladed by the short 15 c.m. B.L. gun.

The crest of the protecting parapet is 3·5 metres above the level of the terreplein, and 2000 metres from the battery. By means of the quadrant the ground angle of this crest is found to be $+ 35'$. In the practice table we find that the angles of descent at 2000 metres are—

with 1·5 k.g. $= 12^\circ\ 20'$.
" 1·4 " $= 13^\circ\ 23'$.
" 1·3 " $= 14^\circ\ 36'$.
" 1·2 " $= 16^\circ\ 5'$.

The distances behind the crest, corresponding to these angles of descent, at which the mean trajectory strikes the terreplein, can be obtained with sufficient exactness by the formula

$$z = \frac{h}{\tan \gamma_1}.$$

We shall have

with 1·5 k.g. $z = 16$ metres.
" 1·4 " $z = 14 \cdot 7$ "
" 1·3 " $z = 13 \cdot 4$ "
" 1·2 " $z = 12 \cdot 1$ "

If we decide to employ the charge of 1·2 k.g. we shall have a strikeable length of terreplein of $80 - 12 = 68$ metres.

The angle of elevation taken from the practice tables (reckoned from the straight line joining the centre of the gun's muzzle and the crest of the parapet) is $14^\circ\ 36'$. In order that the mean trajectory may clear the crest the ground angle must be added to this angle. We have, therefore, $\phi = 14^\circ\ 36' + 35' = 15^\circ\ 11'$.

Finally, in order to bring the mean point of impact to the centre of the strikeable portion of the terreplein, the trajectory must be raised sufficiently to increase the range by $\frac{68}{2}$, or 34 metres; which corresponds to an increase of the elevation by $18'$. We have consequently, for the first trial shot, an angle of elevation of $15^\circ\ 27'$., or in round numbers $15\frac{1}{2}^\circ$.

Since the practice tables give a length of 25·15 metres for 50 per

cent. of hits at 2000 metres, we have $\frac{68}{25 \cdot 15} = 2 \cdot 70$; which, by the tables which give the probability of striking, corresponds to 93 per cent. of hits, provided none of the shots are lost by lateral spread. It follows, therefore, that 7 per cent. of the shots will strike either too short or too long, and that the elevation may be considered sufficient if not more than 3 to 4 per cent. of them strike the parapet.

Ex. 5.—The space between the first and second traverses of a line capable of being enfiladed has to be raked by means of enfilade fire from a short 15 c.m. B.L. gun. The distance of the gun from the crest of the covering parapet is 1250 metres, that of the crest of the parapet from the crest of the first traverse 28 metres, and the horizontal distance of this crest from the foot of the second traverse 12 metres. The crests of the parapet and of the traverse are 4·5 metres above the terreplein, and the line joining the centre of the gun's muzzle and the crest of the parapet makes an angle of 24′ with the horizontal.

If we take the mean point of impact at the foot of the second traverse we shall have

$$\tan \alpha = \frac{4 \cdot 5}{12} = 0 \cdot 375,$$

$$\text{and } \alpha = 20^\circ\ 33'.$$

In order to obtain an angle of descent of $20\frac{1}{2}^\circ$ at the given distance we must employ a very small charge—say a little under 0·6 k.g. Since this charge gives unfavourable results, both as regards the action of the fuzes and accuracy of fire, it appears more advantageous to take the mean point of impact higher—say 3·5 metres below the crest. We shall then have

$$\tan \alpha = \frac{3 \cdot 5}{12} = 0 \cdot 29166.$$

The crest of the covering parapet, and therefore also that of the first traverse, is 1250 × tan 24′ above the level of the muzzle of the gun.

We have, therefore,

$$\tan n_1 = \frac{1250 \tan 24'}{1250 + 28} = 0 \cdot 00683,$$

$$\text{and } n_1 = 23\tfrac{1}{2}',$$

$$\tan n_2 = \frac{1250 \tan 24' - 3 \cdot 5}{1250 + 28 + 12} = 0 \cdot 00405.$$

By formula (1) we have

$$\tan \gamma_1 = \tan \alpha + \tan n_2 = 0 \cdot 29166 + 0 \cdot 00405 = 0 \cdot 29571,$$

$$\text{and } \gamma_1 = 16^\circ\ 28'.$$

For a range of 1278 metres we find in the practice tables that the angle of descent (γ_1) would be 17° 55′ with a charge of 0·7 k.g., and 15° 8′ with one of 0·8 k.g.

The first angle is too large, and the second too small; therefore, taking a mean charge of 0·75 k.g., we shall have

$$\gamma_1 = 16^\circ\ 31\tfrac{1}{2}'.$$

This charge may be looked upon as the right one.

We now interpolate for the angle of elevation corresponding to a charge of 0·75 k.g. and a range of 1278 metres, and obtain

$$\phi_1 = 15^\circ\ 59\tfrac{1}{2}'.$$

As this angle is taken with reference to a line inclined at an angle of $23\frac{1}{2}'$, the angle of elevation, as taken with reference to the horizontal, must be increased by $23\frac{1}{2}'$, and we shall have

$$\phi_0 = 16^\circ\ 23'.$$

8. Method of Proceeding when a Breach has to be Effected by means of Cannelures cut out by Curved Fire.

Owing to the natural dispersion of the projectiles it will very seldom be possible, when breaching by means of curved fire, to cut out the *horizontal cannelure* with the same accuracy as in the case of direct breaching at short ranges, where we commence at one end and shift each individual shot laterally. We have to content ourselves with grouping the hits round certain fixed points by firing 3 to 5 shots at a time with the same laying. According to the observed effects the groups of hits are shifted laterally to a given amount by altering the laying, and in this way a horizontal cut is gradually formed. By a continual repetition of this process the cut becomes deeper and deeper until the scarp is completely penetrated.

In order to carry out this process with uniformity, and to be able to tell at any instant how many times the cut has been fired at from one end to the other, a table is set up in each breaching battery, in which is registered the line of direction of every group of shots delivered.

It is not advisable to cut right through the scarp in one place, and then enlarge the breach till it becomes a horizontal cut. In the case of thick scarps a deep funnel is formed, from the sides of which the projectiles rebound and explode prematurely. Moreover, the funnel becomes filled with the iron splinters, and the penetration of the shells is thereby rendered difficult.

Should the scarp be a very strong one, or should there be reason to apprehend that, owing to the line of fire being oblique, the shells will glance off, we should fire a larger number of them with the same laying and at one particular spot. If plenty of guns are available, or if the scarp is not very strong, we can commence with half the number at one end, and with the remainder at the centre of the space to be breached. Lastly, if we are prevented, either by traverses or by the narrowness of the ditch which has been selected to fire down, from making a breach of sufficient extent, we must cause the guns to cross

their fire—those on the left firing at the right half of the horizontal cut, and those on the right at the left half.

The distance apart at which the groups of hits should be placed depends on the nature of the scarp and the final velocity. If the former is very strong, or the latter small, the centre of each group should be, at the most, only one metre from the next, thus ensuring that every shot shall strike a portion of the scarp which has already been loosened by the preceding ones. In the case of a weaker scarp or a greater final velocity the hits may be placed at $1\frac{1}{2}$ to 2 metres apart; but we must then, in repeating the fire, endeavour to make the shots strike the spaces left between the funnels.

If the line of fire is oblique it is best to commence at the side of the intended breach that lies nearest to the battery, and to shift the groups of hits in succession towards the obtuse angle.

When the correct laying has been obtained the elevation employed in making the horizontal cut is to be retained unaltered, except in the case of a very oblique line of fire, and the only correction to be made will be what may be necessitated by atmospheric influences. It must also be remembered that, with an oblique line of fire, changing the direction laterally alters the range. Thus, at Strasburg, in 1870,* owing to the oblique line of fire, the distance of the left extremity of the breach in Lunette No. 50 from Battery No. 8 was greater by 11 metres than that of the right; consequently, in working the horizontal cutting from right to left, the elevation had to be increased in proportion, and *vice versâ.*

The formation of the vertical cuts is not to be commenced until it becomes certain that the horizontal cut has penetrated the full depth of the scarp for the whole extent of the breach; and this may be known by the earth bursting out along the whole length of the cut. If we cannot satisfy ourselves on this point by direct observation we must judge of it by taking into consideration the strength of the scarp, the line of fire, the final velocity, and the striking power of the projectiles, on the basis of the points particularly to be observed which are treated of more fully in part 12. The vertical cuts should be made as close as possible to the counter-forts, just as in the case of direct breaching.

We can either employ half the guns for each vertical cut, or concentrate the fire of them all on one end only. The first shot is directed on a point 1 to 2 metres above the horizontal cut, the succeeding ones are aimed in the same manner, and when their effect is judged to be sufficient (*i.e.*, when the scarp is completely cut through) the point of impact is moved higher up. At Strasburg it was found best, instead of completing the cutting, to finish about four metres first, and then make a similar cut at the other end, afterwards completing the cuts alternately up to the cordon.

It is also recommended that heavier charges should be employed as the vertical cut increases in height, because time is thereby saved; the elevation being arranged to correspond with the altered position

* Von Decker, Mittheilung über die Anwendung des indirecten Schusses.

of the point of impact, according to the instructions already given. Should, however, the portion of the masonry above the horizontal cut be visible from the gun, it is self-evident that, as in the case of direct fire, the full service charge, with the elevation corresponding to the distance, can be employed. Should counter-forts exist they must be destroyed, and to effect this they must be taken as low down as possible. Lastly, some more shots are still required to bring down with a rush the earth that remains; as, till this is done, a practicable breach will not be produced. Reduced charges are used for this, otherwise the shells would penetrate too deep, and their bursting effect would be lessened. It has also been tried whether firing at the earth in horizontal layers would hasten its downfall; no advantage has, however, been gained by this proceeding.

When the masonry is very strong, old, and compact, the scarp comes down in large blocks, thus rendering the formation of a practicable breach difficult. This was the case at Graudenz, when breaching was being carried on by this method. Under favourable profile conditions these blocks can, it is true, be fired at and smashed up; but it is seldom that this can be done. It is therefore recommended that, before the completion of the vertical cuts, a few shots should be fired at the portion of the scarp which has to be brought down, so as to break it up before it falls.

When the masonry is weak, and the vertical dispersion of the projectiles considerable, the vertical cuts may be dispensed with. This was the case at Strasburg in 1870. In breaching the right face of Lunette No. 53 the distance was 790 metres, the charge 0·85 k.g., and the angle of descent 7° 45′. Lieut.-General von Decker says on the subject*:—"The further process of breaching failed to produce a proper horizontal cut. The vertical dispersion of the projectiles effected much more towards demolishing the scarp; since, along with the gradual breaking through of its lower portion, the upper part as well became destroyed, and fell down in fragments, more or less large, followed by the earth. This unfortunately had the drawback in many cases of diminishing the bursting effect of the shells on the scarp itself. There was no occasion to make a vertical cut. All that had to be done to completely remove the upper half of the scarp was to gradually raise the mean point of impact towards the end of the firing. When this had been effected a large number of shots with a charge of 1·2 k.g. were fired at the earth of the parapet, in order to bring it down. About half the mass of the parapet fell down, and the fragments of masonry were in this way completely covered with earth."

It is very difficult to effect a practicable breach when the revetment is counter-arched, as in Fig. 11. In order to destroy these arches, and bring down the earth above them, the uprights between the arches must be smashed up, and this can only be done successfully when the effects of the fire can be watched.

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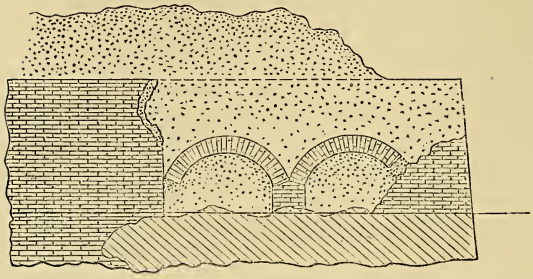
* Mittheilung über die Anwendung des indirecten Schusses.

Fig. 11.



9. Breaching a Scarp by battering its upper half.

In fortresses of modern construction it is no longer considered sufficient to keep the cordon out of sight, and the line connecting the cordon and the top of the covering mass is inclined at a slope of 1 in 5, or even 1 in 4. If, therefore, the lowest point of impact is taken at half the height of the scarp, the angle of descent will be 15° to 20°, or more. In order to get at a scarp protected in this way by means of curved fire we are compelled, not only to reduce the charge considerably, but also to place the battery a long way off. Under such circumstances the large vertical spread of the projectiles renders a systematic breaching out of the question, and we are obliged to content ourselves with effecting a breach by destroying the upper half of the scarp, supposing that the profile conditions allow this to be done.

A Prussian writer* recommends that the portion of the scarp nearest the top be selected as the point to be fired at first, when heavier charges can be employed. In this case, when the scarp has been well cut up and knocked about, the mean point of impact can be gradually lowered by reducing the charge as the penetration of the projectiles increases.

The latest experience gained at Graudenz shows that in this kind of breaching if the *lowest* point of impact be fixed at half the height of the scarp, there is no danger that lowering the point of impact will cause the penetration of the projectiles and their bursting effect to be prejudiced by the mound of masonry fragments and earth that collect in front of the lower portion of the scarp—as was the case at Strasburg in breaching Lunette No. 53, where the lowest point of impact was taken at about a third the height of the scarp.

The French artillery, when breaching Fort Liédot on the Island of Aix in 1863, took the opposite course, in that they endeavoured, by employing small charges and high angles of elevation, to strike the scarp in the first instance at half its height, and afterwards, by increasing the charge and diminishing the elevation, to destroy the upper half of the masonry for the breadth of the breach. Lastly, employing full charges, they bombarded the highest portion of the scarp and the parapet, and thereby caused a downfall of the masonry and earth, thus

* Witte. Artillerie-Lehre, III Theil, 1873.

producing a practicable breach. The most unfavourable case, as regarded the smallness of the charges, happened at Breach No. 10. Only 0·25 metre of the height of the escarp could be seen from the battery. Short rifled 24-prs. were used. The distance was 760 metres, and there were fired—

120	shot	with a charge of	0·675	k.g.	and 10°	elevation
211	"	"	0·835	"	" 8°	"
8	"	"	2·5	"	" 2½°	"

Of the 339 shots fired 258 struck the parapet or scarp, and a practicable breach, 4 metres wide, with a slope of 34°, was formed. The line of fire met the scarp at an angle of 86°. The latter had a thickness of 2·4 metres, and was built of brick. The fort was constructed between the years 1810 and 1836.

The angles of descent may be taken to have been somewhat over 1° greater than the angles of elevation. We have no information as to the initial and final velocities, but the latter were probably about 145 metres with 0·675 k.g., and about 160 metres with 0·835. With a charge of 0·675 the hollow shot, 24 k.g. in weight, penetrated to a depth of from 0·35 to 0·40 metres in the brickwork.

The first of the two methods of breaching mentioned above—viz., by battering the scarp from the top downwards—seems in every sense the more rational; because the masses of masonry which first fall become covered with the earth that subsequently rolls down, and the formation of a practicable breach is thereby materially assisted. If the height of the upper half of the scarp to be breached were inconsiderable, the employment of different charges would appear to be impracticable. The resulting vertical dispersion would, moreover, render unnecessary any change of the point of impact in a vertical direction.

Further experiments must first be undertaken as to how far (with different calibres) the final velocity may be reduced and the angle of descent increased, in order to demolish masonry of various capabilities of resistance sufficiently to produce a practicable breach without disproportionate expenditure of ammunition. In this respect the experiments carried on at Graudenz in 1873 were not sufficiently decisive. Instead of firing with the short 15 c.m. gun, as was intended, and with an oblique line of fire (60°) at 2500 metres, and with a charge of 1·5 k.g., by which an angle of descent of 15° and a final velocity of 208 metres would have been attained, the breaching had, owing to local circumstances, to be effected at 1050 metres, with 1·2 k.g. (final velocity 204 metres), whence resulted an angle of descent of 6° 45′, while an oblique line of fire of 57° 42′ was adopted.

Although, by this means, the normal component of the striking velocity remained the same as would have been the case with the originally intended distance of 2500 metres, the other conditions were materially altered, especially as regarded the probability of striking.*

* With the Austrian short 15 c.m. B.L. gun, and a charge of 1·5 k.g., the 50 per cent. vertical and lateral spread at 2500 metres amounts to 9 and 3·1 metres respectively, and with 1·2 k.g. at 1056 metres to only 2 metres and 1 metre.

After 484 shots, of which 336 struck the scarp, its upper half was in ruins, and a breach 6·5 metres wide was formed, and was considered as practicable. In this instance the peculiar strength of the scarp must be taken into consideration. It was 5 metres thick at the base and 3 at the cordon, and strengthened by counter-forts 4 metres thick and 4·5 metres apart. It carried an earthen parapet 5·6 metres high, which at 1 metre's height above the base had a berm 1 metre wide. The revetment was built of brick, and had behind it a lining wall of very hard blocks of primitive rock.

A breaching experiment carried on at Graudenz under almost exactly similar circumstances, with 21 c.m. B.L. guns, gave also very satisfactory results, in that 190 shots sufficed to produce as practicable a breach as that effected by the 15 c.m. gun. We are therefore justified in the opinion that the method of demolishing the upper half of the scarp by means of curved fire will, in future, supersede the old plan of cannelure cutting. And although, in demolition fire, a greater expenditure of ammunition is necessary to bring down a particular portion of the scarp, this is compensated for afterwards; because a breach produced by horizontal and vertical cuts has still to undergo a further tolerably long bombardment before it is practicable.

In demolition fire the conditions are essentially favourable. The masses of masonry first shot down form a mound of rubbish which lies at a natural slope at the foot of the scarp, and which in no way interferes with the penetration or the bursting effect of the shells which strike the upper half of the scarp. On the contrary, this kind of breaching possesses the advantage that the mound gets more and more augmented and covered with earth at each shot. Moreover, the method of proceeding to be observed during the bombardment is considerably simplified, and it is sufficient to fix the *lowest* point of impact (when deciding on the angle of descent and the charge) at half the height of the scarp, and the *mean* point of impact (when deciding on the elevation) at one-fourth its height from the top. All the complications which are entailed by the formation of the horizontal, to say nothing of the vertical, cuts are avoided, and it is only necessary to shift the mean point of impact laterally from time to time to effect the demolition of the scarp to the desired extent.

10. Calibre, Distance, and Charge.

The short 15 c.m. B.L. gun is the most important and efficacious piece. Except in the case where it is necessary for the projectiles to possess considerable range and striking power, or where light ordnance only can be employed in the armament, this gun is universally applicable in every kind of curved fire.

Owing to their greater bursting effect, the shells 2½ calibres in length are far superior to the ordinary ones, not only for curved breaching and demolition fire, but also for enfilading.

In enfilading entire fronts at a distance of 1500 to 3000 metres both the long 15 c.m. and the short 15 c.m. guns may be employed, and as a rule with heavier charges.

For enfilading particular faces at a distance of 800 to 1500 (or, exceptionally, 1800) metres, the short 15 c.m. gun is the most suitable piece. In the case of badly defiladed lines, where an angle of descent of 10° to 15° is sufficient, the 12 c.m. B.L. gun can be used, if the work to be done consists in disabling the guns between the traverses and clearing out the troops on duty. For cutting away the crests and destroying the traverses this calibre is not to be recommended. When using the short 15 c.m. against well defiladed lines the charge may be reduced to 0·5 k.g. Nevertheless, charges under 0·7 k.g. do not give good results, because they are not sufficient to ensure either regularity of flight or proper action of the fuzes. The short 15 c.m. gun is to be preferred for cutting down and destroying the earthen traverses. The experiments regarding the suitability of the rifled mortar, fired at a low angle, to effect the same object, are not yet concluded.

The long 15 c.m. gun can be used in curved breaching fire if low angles of descent are sufficient. If higher ones are necessitated by the nature of the profiles the short 15 c.m. is the only gun that can be used. In arming captured works for breaching purposes the 12 c.m. B.L. gun of 1861 must, in general, be employed, in the absence of a more handy and powerful piece.

The distances to be taken in the case of the older fortresses lie between 750 and 1200 metres. At the latter limit the breaching will be less systematic and give smaller results. With escarp walls which, in conformance with modern principles, are protected by earthworks, considerably higher angles of descent (20° to 25°) are necessary; and these are only attainable in conjunction with the requisite final velocity at much greater distances, when, in consequence of the large vertical spread, no great result is to be expected from either breaching or demolition fire. In such cases we must try to reduce the height of the covering parapet by means of mines, or by firing at it, and thus, by altering the profile conditions, enable ourselves to employ curved demolition fire against the scarp at a shorter range and with a sufficient final velocity.

In order to determine the limits to which the charge may be reduced it must be borne in mind that, according to all experience, when employing the 15 c.m. gun against moderately strong masonry, a final velocity of at least 160 metres (with the 12 c.m. of 220 metres) is necessary, in order to produce a breach without undue expenditure of ammunition. This (in the case of the short 15 c.m.) indicates a charge of 0·75 k.g. as the smallest that can be used for breaching or demolition fire against a scarp at all capable of resistance.

In the case of a larger calibre—say the 21 c.m.—the object can be attained with a considerably less final velocity, and a high angle of descent is consequently obtainable at a shorter distance. As, however, the vertical spread increases with this angle, and as the heavier the calibre the greater is the difficulty of getting the guns into position, we shall not know, till after the completion of the contemplated experiments, how far the employment of the heavier calibres is advantageous.

At the experiments at Graudenz in 1873, when a 21 c.m. gun and a short 15 c.m. were employed under similar conditions (final velocity 208 metres, angle of descent 6° 45′, obliquity of the line of fire 57°),

to demolish the upper half of a scarp, as good a breach was produced by means of 190 21 c.m. shells (80 k.g. in weight) as by 484 shells from the last-named gun. The total weight of the ammunition (shells and powder together) was 15,900 k.g. in the case of the 21 c.m., and 13,990 k.g. in that of the 15 c.m. The quality of the masonry was in both cases much the same. The 21 c.m. had therefore the advantage as regards the smaller number of projectiles fired. This may possibly be in its favour, owing to time being thus gained, notwithstanding the greater weight of the ammunition expended. This result, however, affords no information as to the suitability of this gun for breaching purposes in the case where, with high angles of descent, the final velocity has to be reduced considerably below the 160 metres which is considered the lowest allowable when using the short 15 c.m. against tolerably strong masonry.

This gun is very suitable for destroying small enclosed works (*Hohlbauten*), detached loopholed walls, &c., at ranges of from 750 to 1500 metres. In the case of larger objects the long 15 c.m. gun of 1861 can be used up to a maximum range of 1800 metres, and with a minimum final velocity of 130 metres.

11. To determine the proper charge and elevation when the covering mass lies nearer to the gun than to the point to be struck.

This case occurs, as was mentioned in the introduction, in curved defensive fire and in curved dismounting fire.

If the relative heights of the cover and of the object with reference to the level of the gun's muzzle are given, and also their horizontal distances from it, the required angle of elevation can be calculated exactly by the formula

$$\tan \phi_2 = \tan n_1 + \tan \alpha.^*$$

The tangent of n_1 will, under the given profile conditions, be always positive. The angle ϕ_2 is reckoned from the line joining the centre of the muzzle and the lowest point of impact (Fig. 6). In order, therefore, to obtain the angle of elevation above the horizontal plane through the muzzle, the angle ϕ_2, found by the above formula, must be diminished, first by the angle of jump (Δ), and further by the ground angle (n_2) of the point of impact, if this point lies below the level of the muzzle. If the contrary is the case the angle $\phi_2 - \Delta$ must be increased by the ground angle (n_2).

In order to calculate the values of $\tan n_1$ and $\tan \alpha$ by the formulas

$$\tan n_1 = \frac{y_1}{x_1}, \text{ and } \tan \alpha = \frac{y_1 \mp y_2}{x_2 - x_1},$$

it must be remembered that the ordinate y_1 must be taken larger than

* The derivation is given in the Handbook for the Austrian Artillery, Part I., Section 4, page 28.

the height of the crest of the cover, in order that none of the projectiles may touch the latter. We must therefore add to the height of the crest at least three times the 50 per cent. vertical spread for the distance x_1. The vertical spread depends, however, on the charge, which latter must in the first instance be settled. In order, therefore, to be perfectly safe, and to avoid all chance of risk, we take three times the 50 per cent. vertical spread for the distance x_1 for the *smallest* allowable charge.

Lastly, in calculating the values of tan α and tan n_2, the position of the lowest point of impact—in other words the value of y_2—must be determined.

In curved defensive fire the objects of fire which have to be taken into account will never be very high. We must take the lowest point of impact at the foot of the object, commence firing with the charge and elevation calculated accordingly, and afterwards, according to the observed effect, raise the point of impact by a corresponding increase of the elevation.

In curved dismounting fire we should take the lowest point of impact at the outer aperture of the embrasure; or, if there are no embrasures, at the outer crest of the parapet, and proceed in the manner just indicated.

If the cover is very close to the gun, or very high, the value of tan n_1, and therefore also the angle of elevation, will be very large; and, at short distances, much too small a charge will be necessitated and considerable vertical spread entailed. On this account the employment of curved defensive fire is very limited, and is in general only possible at the longer ranges.

In curved dismounting fire this inconvenience can be obviated by placing the gun at a greater distance behind the cover, so as to make the ground angle n_1, and consequently ϕ_1, as small as possible, and thus admit of the employment of large charges. In any case the angle n_1 must be smaller than the angle of elevation corresponding to the smallest allowable charge at the given range.

The following example will show what further steps have to be taken to find the charge by means of the practice tables.

Ex.—A short 15 c.m. B.L. gun has to fire over a covering parapet the crest of which is 5 metres above the muzzle and 60 metres in horizontal distance from the gun, at a siege battery 758 metres from the gun, the foot of the battery being 1·4 metres below the level of the muzzle.

From the practice table we find that for 60 metres, with the smallest charge (0·5 k.g.), the 50 per cent. vertical spread is 0·066 metres; we shall therefore have

$$y_1 = 5 + 3 \times 0{\cdot}066 = 5{\cdot}198,$$

$$\tan \phi_2 = \frac{5{\cdot}198}{60} + \frac{5{\cdot}198 + 1{\cdot}4}{758} = 0{\cdot}08663 + 0{\cdot}00704 = 0{\cdot}09367,^*$$

$$\phi_2 = 5^\circ\ 21';$$

* If the angles n_2 and α can be ascertained by means of an instrument for measuring angles, we have $\phi_2 = n_1 + \alpha$ without further calculation. If n_1 and α, as also the horizontal distances x_1 and $x_2 - x_1$ are known, a simple calculation gives the elevation or depression of the point of impact with reference to the level of the muzzle, whence it is easy to calculate n_2.

and as the mean angle of jump may be taken as 6′ the angle of elevation will be 5° 15′.

From the practice tables we find that at the distance of 758 metres the elevation with 1·2 k.g. is 4° 56′, and with 1·1 k.g. 5° 28′. The first angle is too low and would cause the covering parapet to be struck. We choose, therefore, the next *larger* angle of 5° 28′, and the corresponding charge of 1·1 k.g.

We could at once employ this angle if the object was at the same level as the muzzle. As, however, it lies below it, the shot would pass over it with 5° 28′. This angle $(\phi - \Delta)$ must therefore be reduced by the ground angle n_2.

$$\tan n_2 = \frac{1{\cdot}4}{758} = 0{\cdot}001847,$$

$$n_2 = 6'.$$

Consequently, the elevation to be given (ϕ) is 5° 22′.

12. The Method of Laying the Gun; Observing the Effects of the Fire; Correcting the Laying.

Since, when using curved fire, we cannot lay directly on the object, and as, in most cases, the tangent scale can only be employed (if at all) against very slightly marked auxiliary points of aim, the operation of laying the gun in this kind of fire requires particular attention, and the employment of a special aligning apparatus (*Richtvorrichtung*).

Although it is easy to give the necessary elevation (*Höhenrichtung*) correctly by means of the quadrant, still the line of direction (*Seitenrichtung*) and the alteration of the point of impact in a lateral direction offer considerable difficulties, unless the guns are provided with the aligning apparatus for curved fire.

This aligning apparatus consists of two index plates and two directing plates.

The index plates are attached by hinges, the one to the axletree of the gun-carriage, the other to the trail, in such a manner that the zero-points of both plates lie in the plane of symmetry of the gun. In aligning the piece these plates are let down on to the platform; when the gun has been laid they are turned up again and made fast.

The directing plates are fixed by wooden screws to the platform in such a manner that (taking into account the "derivation") when the gun is laid on the object, the similar edges of the directing plates coincide with the zero-points of the index plates when the latter are let down, and are at right angles to their lowest edges. The straight line passing through the longitudinal edges of the directing plates is called the "directing line."

Since the index plates are furnished with a divided scale on both sides of the zero-point, the gun can easily, by their means, be either moved laterally to whatever amount may be required, or be retained in any particular position.

If the direction marked by the directing line is the required one the

zero-points of the index plates must either coincide with the directing line, or be at equal distances from it on one side or the other. An alteration in the direction is effected by moving the rear zero-point to right or left—of course with due regard to the position of the front one at the time.

As regards the amount of the correction to be made, the following is the rule to be observed:—If both the zero-points of the index plates are on the same side of the directing line, the difference of the distances must be equal to the amount of the necessary correction. If, however, one zero-point is to the right and the other to the left of this line, the sum of the distances gives the correction. If it is wished, for instance, to increase (or diminish) the deflection by 1, 2, 3, ... *mm*, the relative difference of the distances must be larger (or smaller) by 1, 2, 3, ... *mm*. In using this aligning apparatus the distances of the zero-points from the directing line, to the right or left—in other words the resulting sums or differences—are to be noted at every round, so that it is always known what amount of alteration it is necessary to make.

By making use of this aligning apparatus all lateral errors in laying are reduced to a minimum, and the laying becomes independent of the amount of light, and can be performed with certainty, even at night.

When *enfilading* at long ranges, or when bombarding the interior of a work, if the object to be struck can be seen from the gun, the laying can be carried on just as in the case of direct fire. If this is not the case we have to lay on a point (to be determined upon by help of a plan) of the cover nearest the object, which will give such a line of fire that the terreplein shall be taken as nearly as possible in the direction of its greatest length. In this case we should only make use of the point of aim in the cover for the purpose of giving the necessary direction to the axis of the piece by means of the deflection scale. The elevation will have to be given by the quadrant.

As, however, the selected auxiliary point of aim is liable to be knocked away, it is only used as a guide for the first shot. When the gun has been laid the directing plates are fixed to the platform in such a manner that their corresponding longitudinal edges coincide with the zero-points of the index plates when let down. Any subsequent alterations in direction that may be required are effected by means of the aligning apparatus.

In *enfilading single faces* at the shorter ranges (with ricochet fire), the elevation is also given by means of the quadrant. To get the gun so placed that its plane of symmetry shall coincide with the plane of alignment (*Richtungs-Ebene*) the plumb-line and pickets are made use of. The latter must be set up separately for each gun, and with their direction either parallel to the crest of the work to be enfiladed, or making a small angle with it. The direction and its correction are given by means of the aligning apparatus.

As the prolongation of the interior crest can only be found with great difficulty, it is better to get the prolongation of the exterior crest instead.

The lines of direction (*Directions Linien*) of the individual guns are

then to be set up at fixed distances apart, and parallel to the ascertained prolongation. For the first gun the distance is equal (at least) to the thickness of the upper part of the parapet of the work to be enfiladed plus half the 50 per cent. lateral spread. The remaining lines of direction are placed at intervals of 7 metres apart, provided the construction of the battery allows of it.

In order to get the prolongation of a line that has to be enfiladed, we choose a time of day when the various lines of the work can be made out by the contrast of light and shade. An exterior slope of a parapet is thus caught by the eye, and we then change our position until the slope appears a line and its crest as a point. The spot where this is the case is on the required prolongation, and is marked by two strong pickets.

The correct prolongation of a line that has to be enfiladed requires considerable practice, and is especially difficult if the work is well defiladed. The planes of alignment of the different guns are marked out by pickets in the central lines of the embrasures converging on the crest of the work to be bombarded. These pickets are set up vertically—the shorter one at the outer edge of the embrasure, the longer one at least a metre from it.

In order to determine the planes of alignment for converging lines of fire we must, by the help of a plan, fix the point of the cover over which the trajectory is to pass. If, then, the inner and longer picket is set up in the line joining the centre of the platform and the point in question, the outer or shorter picket has, by means of the plumb-line, to be fixed in the vertical plane passing through the inner picket and the point of the cover that the shot has to pass over. Where this is not practicable we have to determine by geometrical means how much the outer picket must be moved laterally from the parallel alignment.

In order to align the gun on these pickets we must first mark the pivoting-point (*Drehpunkt*) of the gun on its upper surface by a cone of cobbler's wax, 1 to 2 c.m. high, which is moved to and fro along the line connecting the two sights (*Visirpunkte*) and therefore in the *plane of symmetry* of the piece, until its axis lies exactly in the vertical plane passing through the axis of the axletree-arm. This plane is marked by two plummets, which are held right and left of the gun in such a position that the plumb-lines intersect the central line of the axletree.

With the help of this pivoting-point the gun is moved till its plane of symmetry coincides with the vertical plane of alignment given by the plumb-line and the two pickets. The index-plates are then let down, and the zero-points marked on the platform. The trail is then moved to the right as far as is necessary to give the correction for the derivation, and, lastly, the directing plates are fixed in position.

In the succeeding shots the direction, and whatever correction may at the time be necessitated by the wind, are given by means of the aligning apparatus only.

Laying by means of pickets and plumb-line is very roundabout, and at long ranges is the occasion of considerable lateral spread. This kind of laying is therefore to be looked upon as merely a makeshift for the first trial shot. It can, moreover, be altogether dispensed

with if there are any conspicuous objects in the plane of alignment, either in front of or behind the object of fire, which can be seen from the gun. The direction is then given by means of the tangent scale, the cross-piece of which is set at any convenient height—the derivation being, of course, allowed for.

In enfilading we must endeavour to find suitable elevated spots which will afford a view of the line to be bombarded. If we can make out the individual traverses from a lateral position there will be no difficulty in correcting the laying, since the respective columns of the practice tables give the necessary information, and the same rules will have to be observed as in the case of direct fire. The essential point is to so regulate the direction, according to the amount of wind at the time, and the elevation, that by avoiding firing too short the projectiles may strike the terreplein as quickly as possible.

An alteration of the charge should only be made in very rare instances, because, in enfilading, the amount of curvature of the trajectory is not a matter of importance. If the projectile clears the covering mass it will be in any case more or less efficacious, provided the charge nearly corresponds to the required angle of descent, and is not too large.

If a good view of the traverses and the spaces between them, by means of which the laying could be corrected, cannot be obtained, we must single out and fire at some fixed point, and then, by changing the point of impact, endeavour to attain the object of the bombardment. To this end we select some point of the object that can be plainly seen, and on which the effect of the fire can be easily observed—usually the first traverse—and fire at it in such a manner that the mean trajectory passes through its crest. This may be looked upon as the case when half the shots strike the traverse and the rest pass over it. The point of impact is then to be shifted, by means of the requisite change in the elevation and direction, to the portion of the terreplein that it is intended to hit.

If none of the traverses can be properly seen, we must in the first instance fire at the parapet in front.

If it is necessary to knock away the traverses in order to get at the guns behind them, it is a good plan to take the point of impact, not at the centre of the traverse, but at its innermost end.

When observation is difficult we ought, in order to avoid continually overshooting the mark, to diminish the elevation from time to time by the amount corresponding to the distance of the mean point of impact from the centre of the glacis, when the projectiles will *visibly* fall too short. It may be mentioned here that, owing to the slope of the glacis, the distance from the crest at which the shot strikes this slope is generally over-estimated.

In carrying on *curved breaching or demolition fire* we must, in the first instance (by help of a plan), take the plane of alignment through a point of the parapet above the scarp to be breached (in badly defiladed works through a point of the masonry that can be seen) so situated that the intended point of impact may lie in this plane. The proper direction is given by laying on the visible point by the tangent scale—of course with the necessary deflection.

When the point of aim has been thus selected it must be fired at in the manner directed further on. The charge can be determined according to the instructions in part 7, but not the elevation; because, to get the range, some visible point must be struck, and this point is situated higher than the one which would be taken as the basis of the calculation in determining the elevation in the case of curved fire. The elevation is taken from the practice tables exactly as in the case of direct fire. If the tangent scale suffices for the elevation, its proper height and the deflection for the distance of the visible point of aim can be taken from the table corresponding to the charge to be used—if necessary, by interpolation. If the tangent scale does not suffice, the angle of elevation is determined in a similar manner by means of the tables, and the ground angle of the selected point of aim added to or subtracted from it, according as the latter lies above or below the level of the muzzle. The elevation is given by means of the quadrant, and the required direction by the tangent scale, the cross-piece of which is to be set at its greatest height and then adjusted so as to give the required correction for "derivation."

The trial shots are commenced with this laying. In doing this we endeavour, with a certain number of shots, to attain a mean point of impact close to the selected point of aim above the intended breach.

By the help of the data contained in the tables this mean point of impact can then be easily moved laterally and vertically (downwards), so that the first cluster of hits shall fall upon the desired point, or on one end of the intended breach; the tangent scale being employed, and the gun laid on the auxiliary point of aim.

If we conclude from further observation that the position of this cluster of hits is correct, the same laying will be retained for the succeeding shots, the direction being given by the aligning apparatus by laying down and fixing the directing plates in the line connecting the zero-points of the index plates. The quadrant only is used in giving the elevation.

If now, after thus shifting the point of impact, only a few of the shells, or at most 25 per cent. of them, strike the covering mass, it is a proof that the charge has been correctly chosen. Moreover, under ordinary conditions of weather and with accurately known profiles, the elevation obtained practically in this manner will correspond with that calculated by the rules given in part 7.

If, with the given laying, only a few shells, or none at all, strike the cover, it is a proof that the charge is a little too small. It may, however, be retained without much detriment if the final velocity is sufficient.

If, however, more than half the shells strike the cover, the charge is manifestly too large and must be altered. The trial shooting must then be gone through over again with the new charge.

We may be compelled, in default of a visible object of aim above the scarp to be breached, to fire at the crest of the intervening rampart; though this is a less advantageous method. There is no difficulty in firing at a point of this crest, because the elevation is to be looked upon as correct if half the shells clear the cover and half strike it. If, now, the information afforded by the practice tables were always

applicable, the trajectory would simply have to be raised by half the height of the 50 per cent. vertical spread in order to further utilise 25 per cent. of the lower half of the set of trajectories, and the mean point of impact would then coincide with the intended one. In default of direct observation we must remain in ignorance as to whether or not the elevation so arrived at is correct, or whether the charge calculated according to part 7 should or should not be altered.

The characteristic signs, as ascertained by experiment, which partly take the place of direct observation, and which render possible a correction of the laying, are essentially as follows :—

When a shell strikes sound masonry there appear, immediately after the impact, a radiating shower of stone or brick splinters and dust. The smoke usually rises in a spherical or wreathed form, and is, in general—especially when lighted up by the sun—a decided red if the scarp is of brick, and yellow or dark grey if it is built of stone. In damp weather or rain it is difficult to decide whether the rising dust is from earth or masonry. In the case of wet ditches the water that is thrown up shows that the surface has been struck.

The smoke appears above the intervening crest very soon after the explosion. We can nevertheless distinguish, by the greater or less interval which elapses before the cloud rises, whether the shot has struck high up or near the foot.

When masonry is struck the sound of the explosion is clear and hard. If the shots impinge on brickwork that has been already damaged, the cloud of smoke is as before coloured red, and the shower of brick splinters may be looked for; but the smoke appears later, and rises more slowly and in a less compact shape. The deeper the scarp gets cut into the more clearly can the above-mentioned signs be recognised, and when it has been quite broken through the smoke appears a dark grey colour.

These signs make their appearance in various degrees, and are often difficult to distinguish. It is therefore, in every case, very desirable to obtain direct observation of the effects of the firing from the very first. This is, moreover, absolutely necessary in order to be able to judge with sufficient certainty of the instant when the horizontal and vertical cuts have respectively penetrated right through the scarp, and, afterwards, when the breach is practicable. Lastly, direct observation is indispensable for the completion of the breach when there are counter-forts or counter-arches.

Direct observation may be dispensed with when demolishing *réduits, caponnières, bâtardeaux*, &c., of which the profiles are known.

If, in general, a tolerably practicable breach has to be effected, a favourable point of view somewhere *near the breach* must be made use of; and this presupposes that the glacis has already been crowned. Care must, however, be taken that the crowning does not extend to the part of the glacis which has to be fired over.*

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* At the breaching of Lunette No. 53, during the siege of Strasburg in 1870, it happened that on the night of the 14th–15th September, contrary to an agreement which had been made, the crowning of the glacis was extended to the part which had to be fired over, and the crest of the

The observers must be in telegraphic communication with the battery. For this purpose the employment of the so-called clock telegraph (*Zeiger-Telegraph*), as used by the Military Committee and by some divisions of artillery when practising, is to be recommended.

In the case of *curved defensive fire,* as also in that of curved dismounting fire, we must in the first instance carefully mark by pickets the plane of alignment of each gun. For this purpose the projection of the centre of the muzzle of the gun on the platform is marked by a stake or bandrol. This done, an assistant mounts on the parapet with a picket and plants it as nearly as possible in the plane passing through the bandrol and the intended point of impact.

The next thing is to find an intermediate point between this provisional guiding point and the gun, from which the intended point of impact can be seen, and to align it on the bandrol and the guiding point. This intermediate point is then to be marked by a picket, and the guiding point exactly aligned between it and the intended point of impact.

Lastly, by repeating this process, the centre of the muzzle, the intermediate point, the guiding point, and the point that is to be struck, are brought into the same plane.

In the case of curved defensive fire it is generally possible to make use of some point above or behind the gun in order to bring the guiding point on the parapet into the plane of alignment.

The gun is now to be laid on the guiding point with the deflection corresponding to the range, and the necessary elevation given by means of the quadrant.

Since in this kind of curved fire the protecting parapet, and consequently the guiding point which has been fixed upon it, are tolerably close to the gun, we must, in order to avoid large lateral errors in laying, get the gun into such a position each time that the plane of sighting (*Visir-Ebene*)—*i.e.*, the vertical plane passing through both sights when the deflection has been allowed for—shall coincide with the plane of alignment. In order to avoid this roundabout and difficult process the guns should, as in the other kinds of curved fire, be guided by means of the plumb-line till their plane of symmetry coincides with the marked out plane of alignment, and must be provided with the aligning apparatus, in order that the direction may be given in the usual way. When the directing plates have been laid down and fixed, the direction and its necessary correction are given by means of the aligning apparatus only.

As the effect of the fire will always be watched as much as possible from the covering parapet, there will be no difficulty in applying the ordinary rules in correcting the firing, since the new practice tables give all the necessary information, including the vertical and lateral spread of the projectiles.

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cover was thereby increased in height by 0·66 metre. In order to avoid changing the dispositions which had been made the curved breaching fire was continued with the charge and elevation originally decided on. It took about 120 shots to destroy the portion of the crowning which was in the way.

In order to allow the examples given in this essay to be followed throughout, the corresponding practice tables for the short 15 c.m. B.L. gun are appended.

Although I have endeavoured to discuss the problem of curved fire—so interesting to all artillerists—from a practical rather than a theoretical point of view, on the basis of the experience already gained, I cannot hope to offer to those who are already well acquainted with the literature of this subject anything essentially new. This essay may possibly, however, give rise to discussions upon the subject of this kind of fire, and the difficulties in its employment which present themselves. Such discussions would be the means of thoroughly ventilating the question, and would certainly lead to valuable suggestions being made.

Practice Table.

Nature of Ordnance.—Short 15 c.m. B.L. Gun. Jump or angle by which the discharge increases the elevation (*Erhebungswinkel*) 6′.

Projectile.—Common shell, 2½ calibres in length. *Charge*, 0·9 k.g.

Range.	Deflection.	Height of tangent sight.	Angle of elevation.		Angle of descent.		Time of flight.	Final velocity.	Space within which 50 per cent. of the shells strike. Length.	Breadth.	Height.	Lateral and vertical displacement of the point of impact corresponding to an alteration of 3 m.m. (or about 5′) in the deflection and elevation respectively.	Alteration of range for every 5′ (or about 3 m.m.) of elevation.	Lateral displacement of the point of impact corresponding to every 3 m.m. of the index-plate of the aligning apparatus.
metres.	m.m.	c.m.	°	′	°	′	secs.	metres.						
100 ...	1·5	3·35	0	47	0	53	0·56	177·2	3·72	0·07	0·06	0·14	9·5	0·09
200 ...	2·5	6·40	1	41	1	48	1·14	176·0	4·85	0·14	0·15	0·29		0·19
300 ...	4·0	9·65	2	35	2	44	1·72	174·7	5·97	0·22	0·28	0·43	9·0	0·28
400 ...	5·5	12·95	3	30	3	40	2·31	173·5	7·10	0 30	0·45	0·57		0·38
500 ...	7·0	16·40	4	26	4	39	2·91	172·3	8·23	0·39	0·66	0·71		0·47
600 ...	8·5	19·85	5	23	5	38	3·52	171·2	9·34	0·48	0·91	0·86	8·5	0·57
700 ...	10·0	23·40	6	20	6	39	4·15	170·0	10·49	0·57	1·21	1·00		0 66
800 ...	11·5	27·00	7	19	7	42	4·78	168·8	11·59	0·68	1·56	1·14		0·76
900 ...	13·5	30·70	8	18	8	46	5·43	167·7	12·74	0·78	1·95	1·29	8·0	0·85
1000 ...	15·0	—	9	19	9	52	6·10	166·6	13·87	0·89	2·40	1·43		0·95
1100 ...	16·5	—	10	21	11	0	6·78	165·5	14·99	1·00	2·89	1·57		1 04
1200 ...	18·5	—	11	25	12	10	7·48	164·4	16·13	1·12	3·45	1·72	7·5	1·14
1300 ...	20·0	—	12	31	13	22	8·21	163·3	17·25	1·25	4·08	1·86		1·23
1400 ...	22·0	—	13	38	14	37	8·93	162·3	18·38	1·37	4·76	2·00	7·0	1·32
1500 ...	24·0	—	14	47	15	55	9·69	161·3	19·51	1·51	5·53	2·14		1·42
1600 ...	26·0	—	15	59	17	16	10·47	160·3	20·64	1·64	6·38	2·29	6·5	1·51
1700 ...	28·5	—	17	13	18	40	11·29	159·4	21·77	1·78	7·31	2·43		1·61
1800 ...	30·5	—	18	31	20	9	12·13	158·5	22·89	1·93	8·34	2·57	6·0	1·70
1900 ...	33·0	—	19	52	21	41	13·01	157·6	24·02	2·08	9·49	2·72		1·80
2000 ...	35·5	—	21	18	23	20	13·94	156·8	25·15	2·24	10·78	2·86	5·5	1·89

Practice Table.

Nature of Ordnance.—Short 15 c.m. B.L. Gun. Jump or angle by which the discharge increases the elevation (*Erhebungswinkel*) 6′.

Projectile.—Common shell, 2½ calibres in length. *Charge*, 0·8 k.g.

Range.	Deflection.	Height of tangent sight.	Angle of elevation.	Angle of descent.	Time of flight.	Final velocity.	Space within which 50 per cent. of the shells strike. Length.	Breadth.	Height.	Lateral and vertical displacement of the point of impact corresponding to an alteration of 3 m.m. (or about 5′) in the deflection and elevation respectively.	Alteration of range for every 5′ (or about 3 m.m.) of elevation.	Lateral displacement of the point of impact corresponding to every 3 m.m. of the index-plate of the aligning apparatus.
metres.	m.m.	c.m.	° ′	° ′	secs.	metres.						
100 ...	1·5	3·86	0 55	1 1	0·60	165·7	3·72	0·07	0·07	0·14		0·09
200 ...	3·0	7·35	1 56	2 3	1·21	164·6	4·85	0·14	0·17	0·29	8·0	0·19
300 ...	5·0	11·05	2 59	3 7	1·82	163·4	5·97	0·22	0·32	0·43		0·28
400 ...	6·5	14·90	4 2	4 12	2·44	162·3	7·10	0·30	0·52	0·57		0·38
500 ...	8·0	18·80	5 6	5 19	3·06	161·2	8·23	0·39	0·76	0·71		0·47
600 ...	10·0	22·80	6 11	6 27	3·69	160·1	9·34	0·48	1·05	0·86	7·5	0·57
700 ...	11·5	26·90	7 17	7 37	4·34	159·0	10·49	0·57	1·39	1·00		0·66
800 ...	13·5	31·05	8 24	8 49	4·99	157·9	11·59	0·68	1·79	1·14		0·76
900 ...	15·5	—	9 33	10 4	5·65	156·9	12·74	0·78	2·25	1·29	7·0	0·85
1000 ...	17·5	—	10 44	11 26	6·32	155·9	13·87	0·89	2·76	1·43		0·95
1100 ...	19·5	—	11 57	12 40	7·01	154·8	14·99	1·00	3·35	1·57		1·04
1200 ...	21·5	—	13 11	14 2	7·71	153·9	16·13	1·12	4·00	1·72	6·5	1·14
1300 ...	23·5	—	14 29	15 27	8·43	152·9	17·25	1·25	4·74	1·86		1·23
1400 ...	26·0	—	15 49	16 56	9·17	152·0	18·38	1·37	5·56	2·00	6·0	1·32
1500 ...	28·5	—	17 12	18 29	9·93	151·1	19·51	1·51	6·48	2·14		1·42
1600 ...	31·0	—	18 39	20 7	10·72	150·2	20·64	1·64	7·51	2·29	5·5	1·51
1700 ...	33·5	—	20 11	21 50	11·57	149·4	21·77	1·78	8·67	2·43	5·0	1·61
1800 ...	36·5	—	21 48	23 40	12·41	148·6	22·89	1·93	9·94	2·57		1·70
1900 ...	39·5	—	23 32	25 37	13·32	147·9	24·02	2·08	11·44	2·72	4·5	1·80
2000 ...	43·5	—	25 25	27 44	14·29	147·2	25·15	2·24	13·14	2·86	4·0	1·89

Practice Table.

Nature of Ordnance.—Short 15 c.m. B.L. Gun. Jump or angle by which the discharge increases the elevation (*Erhebungswinkel*) 6′.

Projectile.—Common shell, 2½ calibres in length. *Charge*, 0·7 k.g.

Range.	Deflection.	Height of tangent scale.	Angle of elevation.	Angle of descent.	Time of flight.	Final velocity.	Space within which 50 per cent. of the shells strike. Length.	Breadth.	Height.	Lateral and vertical displacement of the point of impact corresponding to an alteration of 3 m.m. (or about 5′) in the deflection and elevation respectively.	Alteration of range for every 5′ (or about 3 m.m.) of elevation.	Lateral displacement of the point of impact corresponding to every 3 m.m. of the index-plate of the aligning apparatus.
metres.	m.m.	c.m.	° ′	° ′	secs.	metres.						
100 ...	2·0	4·40	1 5	1 11	0·65	153·5	3·72	0·07	0·08	0·14		0·09
200 ...	3·5	8·55	2 17	2 24	1·31	152·5	4·85	0·14	0·20	0·29	7·0	0·19
300 ...	5·5	12·95	3 29	3 38	1·99	151·4	5·97	0·22	0·38	0·43		0·28
400 ...	7·5	17·40	4 43	4 54	2·67	150·4	7·10	0·30	0·61	0·57		0·38
500 ..	9·5	22·00	5 58	6 12	3·37	149·3	8·23	0·39	0·89	0·71		0·47
600 ...	11·5	26·70	7 14	7 32	4·08	148·3	9·34	0·48	1·23	0·86	6·5	0·57
700 ...	13·5	31·55	8 32	8 55	4·81	147·3	10·49	0·57	1·63	1·00		0·66
800 ...	16·0	—	9 52	10 20	5·56	146·3	11·59	0·68	2·10	1·14		0·76
900 ...	18·0	—	11 14	11 48	6·33	145·4	12·74	0·78	2·65	1·39	6·0	0·85
1000 ..	20·5	—	12 39	13 20	7·12	144·5	13·87	0·89	3·37	1·43		0·95
1100 ..	23·0	—	14 6	14 55	7·90	143·7	14·99	1·00	3·97	1·57	5·5	1·04
1200 ...	25·5	—	15 37	16 35	8·79	142·7	16·13	1·12	4·77	1·72		1·14
1300 ...	28·5	—	17 12	18 19	9·67	141·8	17·25	1·25	5·68	1·86	5·0	1·23
1400 ...	31·0	—	18 52	20 10	10·60	141·0	18·38	1·37	6·70	2·00	4·5	1·32
1500 ...	34·5	—	20 38	22 7	11·57	140·2	19·51	1·51	7·88	2·14		1·42
1600 ...	38·0	—	22 31	24 13	12·60	139·5	20·64	1·64	9·22	2·29	4·0	1·51
1700 ...	41·5	—	24 34	26 29	13·72	138·8	21·77	1·78	10·78	2·43	3·5	1·61
1800 ...	46·0	—	26 50	29 0	14·93	138·2	22·89	1·93	12·61	2·57	3·0	1·70
1900 ...	52·5	—	29 26	31 52	16·30	137·7	24·02	2·08	14·84	2·72	2·5	1·80
2000 ...	58·5	—	32 34	35 15	16·99	137·4	25·15	2·24	17·66	2·86	2·0	1·89

RECENT IMPROVEMENTS

IN THE

MANUFACTURE OF PEBBLE-POWDER.

BY

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THE points to be attained, as is well known, in any improvements in the manufacture of powders, are an increased velocity of projectile, a diminished strain on the gun, and greater uniformity of results. It was the introduction of heavy and rifled guns that drew attention to the importance of these points, and we accordingly find that as the size and precision of fire of guns have increased, the necessity for improved gunpowder has been felt in all countries. In a paper published in 1871,* the author entered very fully into the methods which have been used for determining the explosive force of gunpowder, showing that it is to Captain Rodman, of the United States' army, that we are indebted for having first taught us how the pressure of gunpowder may be measured in the bore of the gun in which it is fired. This is the only satisfactory way of solving the question, and we accordingly find that his experiments led to the discovery that the means of moderating the rate of combustion of gunpowder lay not only in increasing the size of the grain, but also in increasing the density. Thus originated the American mammoth and perforated cake powders, which have since found their way in modified forms into all countries where the art of powder-making has advanced. The prismatic powder, which has been adopted in Russia and Prussia, is derived from the American perforated cake, and the mammoth powder has appeared in Belgium as "*poudre à gros grain,*" and is slowly making its way into France, Italy, and other continental countries. It has been imported into England under the name of "pebble-powder."

As early as 1858, a Special Committee on gunpowder was appointed under the presidency of Colonel Askwith, then Superintendent of the Royal Gunpowder Factory, Waltham Abbey, and their investigations resulted first in the introduction of R.L.G., and afterwards in the recommendation of "pellet-powder" for heavy guns. In their final Report in 1866 they recommended

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* On "The Determination of the Explosive Force of Gunpowder." See "Proceedings R.A. Institution," Vol. VII., p. 413 *et seq.*

that extensive and systematic experiments should be carried out with the latter powder. They also tried experiments with a pebble-powder which then went by the name of $2A_4$. It was made at Waltham Abbey, in imitation of the American mammoth powder, by breaking up press-cake with copper hammers, and sifting the pieces between meshes of 1 and 2 to the inch. The effect of density in modifying the action of powder was overlooked, and this powder when fired in the B.L. guns was found not only to destroy the vent-pieces, but also to enlarge the chambers of the guns—the latter circumstance showing that the fault lay not in the guns but in the gunpowder. It differed from the American mammoth in one very important respect, being only 1·62 instead of 1·82—which is the American density for both cannon and mammoth powders. It is unfortunate that further experiments were not tried with higher densities, as it is probable that thus we should have had our pebble-powder much sooner than has been the case. The importance of density, however, was not at that time so well understood as it now is, and there appears to have been a bias on the minds of some of the members of the Committee in favour of regular grains pressed separately in moulds, which process they considered also could be carried on more economically than the granulation of $2A_4$ powder, where there was a great amount of waste.

The introduction of the mercurial densimeter at a later period allowed the question of density to be more satisfactorily dealt with. This instrument was first designed in France, and was used for some time in the Chemical Department, Royal Arsenal, before it was introduced into the Royal Gunpowder Factory at Waltham Abbey in 1869.

The present Committee on Explosives, under the presidency of Colonel Younghusband, Superintendent Royal Gunpowder Factory, Waltham Abbey, was appointed in 1869, and conducted an extensive series of experiments with various powders by methods similar to those used by Rodman, which led them to the conclusion that pebble-powder was better suited to the requirements of the service than pellet-powder. As it is also now very much easier and safer to manufacture, the change they recommended from pellet to pebble is not to be regretted. It is the slow and steady progress in the manufacture of this powder that forms the subject of this paper, and which will best be explained by giving a short historical sketch of the process as carried out at Waltham Abbey, and by those merchants who have supplied pebble-powder under contract. Dependence may be placed upon the facts adduced; but it will be well to be cautious in accepting too readily the conclusions drawn, because there is no subject where hasty conclusions are so apt to be overthrown as is the case with the manufacture of pebble-powder.

The first specification sealed to govern the manufacture was 16. 5. 70, the density being 1·8, the size of grain between $\frac{5}{8}$ and $\frac{1}{2}$ in., and when fired in the 8-in. gun the velocity between 1420 and 1480 f.s., and the pressure in no case to exceed 20 tons in the bore of the gun, as indicated by the "crusher" gauges in use by the Committee. Soon afterwards, however, it was found there was a difficulty in maintaining the velocity, and the specification was altered as regards density, with a view to meet the requirements of the case, being lowered to 1·765 in August the same year. Some powder had been made having a density of 1·8, but it was kept in reserve, and afterwards mixed with pebble having a lower density, so as to give a mean of 1·765. The manufacture was continued at this density, and as the proof in the

8-in. gun was satisfactory, it was imagined no further difficulty would be experienced.

The method at first adopted of breaking up the press-cake into pebbles was the same as that described for producing the $2A_4$ grains—viz., the use of copper hammers. This is manifestly a very tedious and troublesome process. It is still, however, to be seen in operation at the Wetteren Factory, in Belgium, where the cake is first cut into strips by a sort of guillotine machine, and afterwards broken up in this fashion, by means of wooden mallets in a hollow hemispherical bowl, into pebbles.

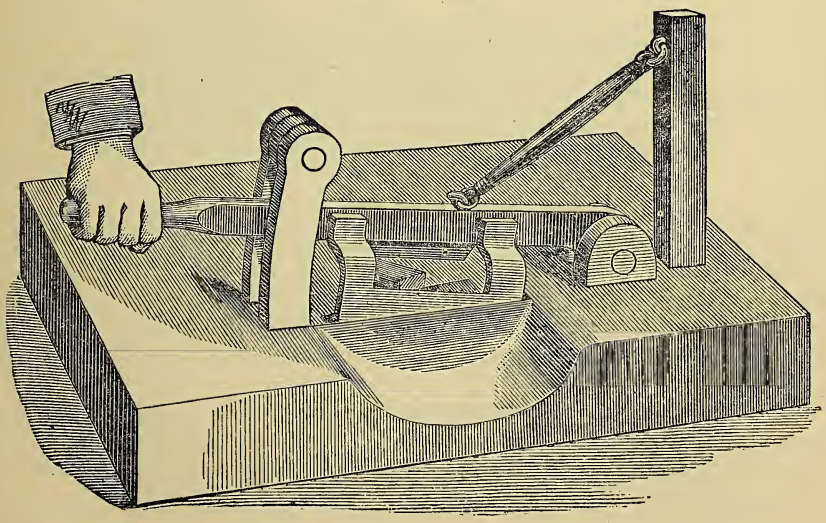
A system of chopping up the cake by means of copper knives very soon superseded the method of breaking up by hammers at Waltham Abbey. The cake was first cut up into strips by the knives, and these strips were again chopped across into pebbles by the same instrument. It was, of course, a tedious process, but it had the advantage of making little or no waste, and nearly the whole of the press-cake could thus be converted into grain.

A good many experiments were tried with a view to granulate the pebbles in the same way as ordinary powders, but all the attempts were very unpromising, owing to the irregularity of the grains and the great amount of waste. Messrs. Curtis and Harvey, however, produced a large proportion of their pebble-powder supplied by contract in this manner. They only, however, obtain about 30 per cent. of grain from their cake; and though this low per-centage does not inconvenience them, inasmuch as they can find other uses for the smaller grains, it would not be sufficient in a Government factory, where there is no other use to which they could be applied.

The chopping-knife was in operation for a considerable time, and turned out the whole of the pebble manufactured at Waltham Abbey from August 1870 to May 1871, during which time about 4000 barrels of 125 lbs. each were manufactured and sent to Purfleet.

The following woodcut will serve to give an idea of the nature of these instruments:—

FIG. 1. Scale $\frac{1}{8}$.



One man could thus cut about 150 lbs. a day, so that the granulation of pebble-powder at that time required the continual employment of nearly 20 men for the very small out-turn of about 100 barrels a week.

The following extracts from the proof books will show the nature of the powder manufactured at this time:—

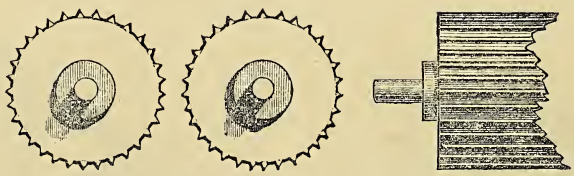
Brand of powder.	Density.	Date of experiment.	Number of experiment.	Muzzle velocity.	Pressures in tons.		
					A.	B.	C.
15. 10. 70	1·761	27. 10. 70	357	1469	17·1	18·1	16·3
14. 11. 70	1·765	8. 12. 70	367	1446	18·1	18·0	15·6
31. 12. 70	1·757	1. 2. 71	389	1409	15·4	15·4	14·6
21. 1. 71	1·759	1. 2. 71	392	1409	12·6	13·1	12·1
3. 2. 71	1·761	20. 3. 71	408	1405	14·1	14·2	13·9
25. 3. 71	1·759	5. 4. 71	440	1406	15·5	15·0	14·8

It will be observed that there is a steady decrease in the velocity at proof. Some of the velocities are even lower; but these samples give an idea of the general average of the work produced at this time.

Meanwhile experiments were being carried on with a view to turn out pebbles in larger quantities and more economically than by the tedious process of chopping up with knives. The late Captain Smith, R.A.—at that time Assistant Superintendent at Waltham Abbey—hit upon a plan which was very successful in doing the same sort of work.

This was by making a succession of knives come into operation one after the other, by being arranged longitudinally on the circumference of two long rollers in the following fashion:—

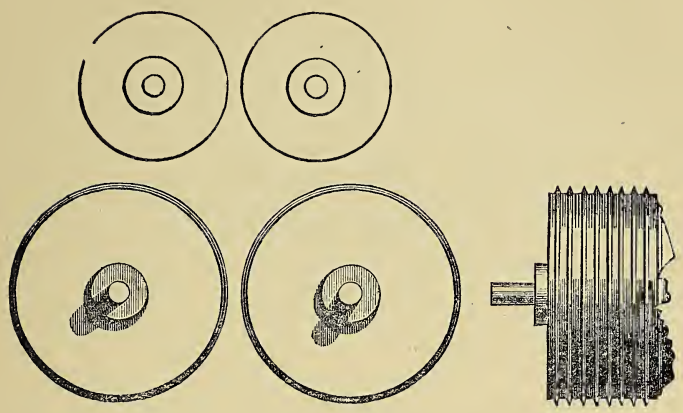
Fig. 2. Scale $\frac{1}{12}$.



The cake was thus very rapidly cut up into strips, but in putting the latter through the second time endways much time was lost, as each strip had to be picked up separately by hand before being put through. He contemplated having a second pair of rollers of the same description as the first, for the strips to pass through, but was unable to devise a method of conveying them from the first to the second pair of rollers, and so his plan for a time remained in abeyance.

Colonel Younghusband thought that the strips could be conveyed, as they passed the first pair of rollers, in succession to a second pair, which had the knives arranged circumferentially instead of longitudinally, as shown in the following woodcut:—

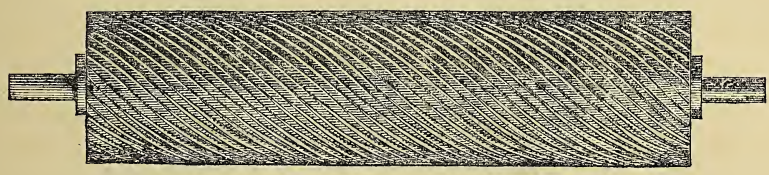
FIG. 3. Scale $\frac{1}{12}$.



He found, however, that the strips would not drop horizontally on to the second pair of rollers, but that they dropped as often endways as sideways, and generally that they fell in all directions, owing to the unevenness of the press-cake from which they were cut.

Mr. Pigou, of Pigou and Wilks', designed a very ingenious pair of rollers which performed the work of cutting up the cake into pebbles in one operation. Both rollers were identical, and had the knives arranged neither longitudinally nor circumferentially, but spirally, at an angle of 45° round the surface. The knives thus crossed each other perpendicularly at the cutting points, and very tolerable granulation was effected. The pebbles, however, were very irregular in shape, and by no means so cubical as those cut up by knives. The following woodcut of Mr. Pigou's roller is given to show the nature of the arrangement:—

FIG. 4. Scale $\frac{1}{12}$.



It had hitherto been supposed that the more uniform the size and shape of the grain, the better would be the results at proof; but while Waltham Abbey pebble seemed to be failing at proof, Mr. Pigou's pebble gave very good results, as shown by the following experiment:—

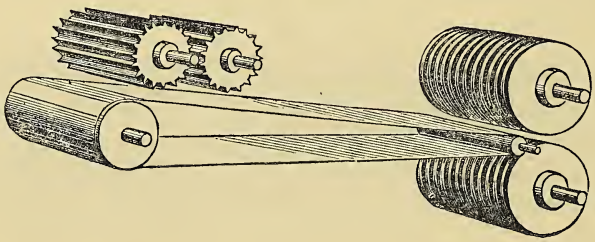
Powder.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
Lot 826...	1·765	28. 3. 71	428	1460	16·5	16·4	15·8

It was at this time that the author was appointed Assistant Superintendent in succession to Captain Smith; and, being impregnated with the then currently accepted theory that the rate of combustion of the charge depended mainly on the amount of surface of powder under combustion, he suggested to Colonel Younghusband that probably the fact that Mr. Pigou's sample consisted of irregularly shaped grains was the reason why he obtained a better velocity than could be obtained with the Waltham Abbey regular cubes, because the irregularly shaped grains would present larger surfaces for initial ignition. It would not do to use small grains, because they would interfere with the passage of the flame in igniting the charge; but there could be no objection to large irregularly shaped grains. Colonel Younghusband tried the experiment, and used the larger rollers in an ordinary granulating machine to break up press-cake into irregular grains. This was mixed with knife-cut pebbles, and, on firing a sample of the ordinary work in comparison, the following result was obtained:—

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
25. 4. 71	1·770	2. 5. 71	483	1399	16·9	16·6	15·6
25. 4. 71 Granl.P.	—	2. 5. 71	485	1436	19·4	19·3	19·7

It seemed to the author that, in Colonel Younghusband's machine, the strips might be made to rectify themselves by being allowed, in the first instance, to drop on a canvas band which, as it travelled, would convey each strip forward so as to allow the next to drop behind it, and afterwards convey the strips in succession in the proper position to pass through the second pair of rollers as follows:—

Fig. 5. Scale $\frac{1}{30}$.



This plan was tried, and was found to answer quite successfully. A very simple machine thus constructed was in operation from the end of May 1871 to March 1872. The following is the proof of the first sample turned out by this machine:—

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
19. 5. 71	1·768	24. 5. 71	534	1475	20·9	20·3	20·0

It will be seen that the velocity and pressure are both high, which is no doubt due to the fact that the pebbles turned out by this machine were smaller than the hand-cut pebbles. The results obtained, however, seem to meet the requirements of the case, especially as the out-turn of the machine was only about 40 barrels a day. The capabilities of the factory in the other processes of manufacture are much greater, and so the chopping process was continued, and the pebbles produced by both processes were mixed together, and the total out-turn increased from about 100 barrels to nearly 300 a week.

Colonel Younghusband tried an experiment to compare directly the work produced by hand-cut and machine-cut pebbles, not only with the ordinary work of the factory, but also with work which had been milled with an increased amount of moisture in the charges, with the following results:—

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
OK. 2. 6. 71	1·768	10. 6. 71	549	1440	19·4	19·8	18·6
HK. 2. 6. 71	1·782	10. 6. 71	550	1444	16·7	15 6	16·3
OM. 7. 6. 71	1·787	16. 6. 71	570	1445	19·7	17·4	16·6
HM. 7. 6. 71	1·782	16. 6. 71	579	1437	19·6	18·8	18·0

It will be seen that there is not very much choice, but that on the whole the charges worked "heavy," or with the increased per-centage of moisture, produce the best results. The more moisture in the powder the less is the danger arising from an explosion in the mills, and the charges were accordingly afterwards worked heavy.

All stovings are proved in the 8-in. gun, and those which meet the required tests are at once "branded," and passed into the service. The others are mixed in a manner calculated to produce the required results. The velocities and pressures obtained at proof are always a matter of considerable uncertainty. The various stovings may be compared to different vintages of wine. There is an uncertain control over the stovings, but after proof within certain limits any brand required can be produced.

A regular systematic mixing had to be established, so as to work off and send away the manufactured powder as speedily as possible after proof. At first the stovings were mixed, in a rough and ready way, by two men, each taking a barrel and alternately pouring a small portion of the contents into another barrel; but very soon a more methodical and satisfactory plan was established.

It appeared to the author that, in order that any system of mixing should be a success, some plan must be adopted of securing that each stoving itself should be perfectly uniform. It appeared vain to attempt to work to densities; for, from the samples already given, it will be seen that density, taken alone, is no criterion of what may be expected at proof. A mechanical system of mixing seemed to promise the best results, and this plan was adopted. In order to do this with as little trouble as possible, advantage was taken of some of the processes of manufacture.

A glazing, as a rule, consists of four large barrels or churns, each of which contains about four small barrels of powder. As these churns revolve at 37 revolutions a minute for four hours, it may safely be assumed that the contents of each churn are well and uniformly mixed. It by no means follows,

however, that the contents of one churn are of the same character as those of the others.

The next process is the stoving, and advantage is taken of the method of setting the stove to make the whole of one glazing perfectly uniform. The powder is set in trays, each tray containing four bowlfuls, or about 16 lbs. In filling a tray, a bowlful is taken from each churn, and thus every tray of a glazing contains exactly the same powder. The glazings are marked off separately in the stove. After stoving, the powder is finished by being revolved about 20 minutes in reels which contain four barrels each, and, as the stove contains four glazings, this gives the required facility for making the whole contents of a stove uniform, because into each reel can be put one barrel from each glazing. No process has been attended with greater certainty in producing uniform powder than this system of mechanical mixing. It gives no extra work, and requires only a little care and attention on the part of the workmen.

Though each stoving, however, is perfectly uniform, it will be seen by the following proofs that different stovings are by no means of the same character. These stovings are selected as giving as near as possible an average of the work turned out, some being higher and some lower as regards velocities and pressures.

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
26. 6. 71	1·772	14. 7. 71	648	1461	21·4	21·6	19·4
30. 6. 71	1·792	5. 7. 71	627	1332	11·5	11·1	11·0
10. 7. 71	1·792	14. 8. 71	59	1385	14·4	14·2	13·8
29. 7. 71	1·763	7. 8. 71	38	1507	22·8	20·7	20·0
9. 8. 71	1·758	18. 8. 71	80	1400	14·6	15·0	14·4
18. 8. 71	1·776	25. 8. 71	101	1442	17·8	17·5	16·6
28. 8. 71	1·777	6. 9. 71	134	1408	16·3	16·2	15·0
1. 9. 71	1·784	6. 9. 71	137	1358	13·3	13·4	13·4
26. 9. 71	1·762	9. 10. 71	225	1436	18·4	18·3	17·1
3. 10. 71	1·753	13. 10. 71	253	1440	17·2	17·2	16.7
18. 10. 71	1·765	27. 10. 71	298	1438	18·5	19·2	17·1
1. 11. 71	1·768	9. 11. 71	336	1428	16·1	16·3	16·4
13. 11. 71	1·736	23. 11. 71	375	1469	17·4	18·4	17·8
16. 11. 71	1·735	23. 11. 71	377	1512	19·9	21·2	21·0
17. 11. 71	1·736	23. 11. 71	378	1534	25·1	24·9	23·5
17. 12. 71	1·750	15. 12. 71	459	1438	14·8	16·2	16·1
15. 12. 71	1·750	2. 1. 72	501	1396	13·3	12·3	12·8
28. 12. 71	1·755	3. 1. 72	524	1391	15·1	14·3	14·4

It will be observed that, though a good many of these stovings are within the limits of the specification, some are very much too low in velocity, while others are too high, both as regards velocity and pressure. Those stovings which were too high in velocity or pressure were mixed with others which were of low velocity and pressure, so as to give a mean result within the specification. This was attended with little inconvenience, as long as the mean results of proof fell within the specification, but it was rather troublesome when there was a long series of proofs of the same character. Some of the proofs, it will be observed, are either exceptionally high or exceptionally low. With regard to stoving 30. 6. 71, the following note is extracted from the proof-book, in Colonel Younghusband's handwriting:—"1000 grs. sample of this powder was dried by Mr. Abel for five hours at 200° Fah., resulting in a loss of only

0·33 per cent.; proving that the very low velocity was not caused by moisture."

Stovings 16 and 17. 11. 71 call for special remark. Every enquiry was made as to the possible cause of the low densities and high pressures and velocities, but nothing could be traced, excepting that the Chief Foreman believed that the charcoal had been overburnt. As this fact at the time was thought calculated to produce the opposite effect, the real cause appeared to be a mystery.

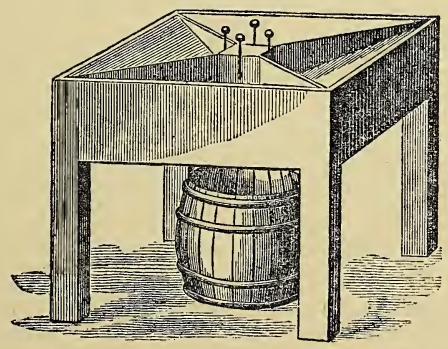
The change from the old to the new gun does not appear to make much difference, as it will be observed that there are low velocities with the new as well as with the old. This latter point was not, however, left purely to speculation, for Colonel Younghusband tried identical samples in both guns, with the following results:—

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
26. 6. 71	1·772	14. 7. 71	647	1460	21·5	20·6	18·5
Ditto	do.	do.	648	1461	21·4	21·0	19·4
5. 7. 71	1·789	12. 7. 71	638	1368	13·6	13·5	13·0
Mean of above, mixed, 2 to 1	—	—	—	1436	18·8	18·4	17·0
Do., 2 to 1 in old gun	—	14. 7. 71	650	1420	18·9	17·6	16·5
			652	1450	19·5	19·5	18·1
			653	1454	20·4	19·8	18·7
Do., 2 to 1 in new gun	—	31. 7. 71	7	1439	17·6	17·2	16·3
			8	1453	18·7	18·9	17·5
			9	1449	19·8	19·8	18·1

The plan of mixing the stovings, as already stated, was at first by hand, but towards the end of 1871 a four-way hopper was made, which materially assisted this process. Sometimes the stovings were mixed two and two, and sometimes four and four, according to the circumstances of the case.

The following woodcut will give an idea of this hopper:—

Fig. 6. Scale $\frac{1}{30}$.



This brings the manufacture at Waltham Abbey down to the end of 1871, and it will be observed that the old tendency to low velocity again begins to manifest itself; and as this tendency appeared on the whole rather to get worse than better, it began to become troublesome. Not only at Waltham

Abbey did it show itself, but in nearly all the powder sent in by the merchants by contract. Lot after lot manufactured by Messrs. Curtis and Harvey, and by the Kames Company especially, showed the same failing; and the question of the manufacture of pebble began to look serious.

The new year, however, introduced a new era. A sudden fit of inspiration seized Colonel Younghusband, and he ordered two samples to be re-stoved. Behold the result!—

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
10. 1. 72	1·765	24. 1. 72	605	1398	15·8	15·5	14·8
Do. re-dried	—	31. 1. 72	677	1455	20·9	20·3	18·5
12. 1. 72	1·763	24. 1. 72	606	1367	13·8	13·8	13·8
Do. re-dried	—	31. 1. 72	678	1418	15·6	13·6	14·6

It was a great relief to have discovered the reason at last. Doubtless the reader will think it was very foolish not to have discovered it sooner; but he should suspend his judgment till he has heard the whole state of the case. Meanwhile it may be observed that the cause had been suspected, and, as has been stated, a sample sent to the Chemical Department for analysis showed a very small loss of moisture. The powder had received the usual amount of stoving. But, what is of more importance is, that when the discovery was communicated to the merchants, with a view to assist them out of their difficulties, one and all refused to believe it.

At Kames an experiment was made to test the matter roughly, by weighing a large sample before re-stoving, and weighing it again afterwards, and, as only a slight difference of weight was detected, it was concluded that the fault of Kames' powder did not lie in its insufficient drying. An experiment was afterwards made at Waltham Abbey with some of Kames' pebble, which partly bears out the result. Two samples were re-stoved, and fired as follows:—

Brand of powder.	Density.	Moisture.	Experiment.		M. V.	Pressures.		
			Date.	No.		A.	B.	C.
Lot 86	1·772	1·17	21. 5. 72	964	1338	16·1	16·1	14·8
Do., re-dried.	—	·898	7. 6. 72	1030	1394	19·3	17·6	17·0
Lot 97	1·755	1·14	21. 5. 72	968	1336	16·2	16·4	15·0
Do., re-dried.	—	·816	7. 6. 72	1031	1379	18·2	18·5	15·8

It will be observed that in the original samples there is no excessive amount of moisture, but rather under the normal amount, if anything, and the re-dried samples may be considered over-dried.

The discovery of the great effect of moisture on velocity and pressure opened up a very large question, and threw discredit to some extent on all the experiments which had hitherto been made, seeing that it could not be told to what extent all the results had been vitiated by an unknown amount of moisture which existed in the samples fired. It at once explained why there had been so much low-velocity powder a year before, and there can be no doubt that, had the reason been known in time, it would have been better to have re-dried some of the powder which had been mixed.

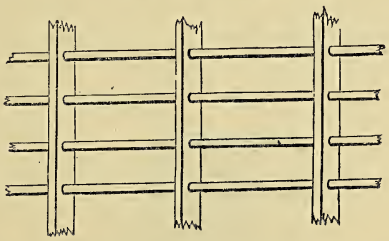
The manufacture continued as before, with varying results; sometimes the

proofs were right, and sometimes they were too low—in which case they were re-dried, or mixed with others that were too high.

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
8. 2. 72.....	1·756	15. 2. 72	710	1427	18·8	17·5	16·5
21. 2. 72	1·754	29. 2. 72	739	1478	17·9	18·2	17·3
4. 3. 72	1·762	7. 3. 72	778	1389	16·4	15·6	15·8
Do., re-dried ...	—	13. 3. 72	—	1466	18 1	18·6	18·0
23. 3. 72.....	1·762	8. 4. 72	900	1430	20·3	19·1	17·8

The last sample, it will be observed, shows a falling off in the powder, and the reason is to be explained as follows. A new machine on Colonel Younghusband's principle had been made, and had just then come into operation. It turned out so large a quantity of pebble as to allow of the more expensive process of cutting by knives being dispensed with. The machine was calculated to give pebbles as large as with the knives, but evidently there was a fault somewhere. On examination it was found that there were a great number of flakey pebbles, of the description of cubes, divided down the middle. They thus were in length and breadth of the proper dimensions, but in thickness only half of what they ought to be. This, in the opinion of the author, was due to the faulty principle of the second pair of rollers, which did not allow of the strips extending outwards, as they were being cut. Though they were very detrimental to the proof of the powder, they could not be removed by the ordinary method of sifting. He succeeded in removing them, however, by the device of an oblong mesh of the following pattern :—

Fig. 7. Scale ½.



When being sifted, the flakey pebbles tilted on their edges and passed through, while the ordinary pebbles were retained. It was found that the system of re-drying was rather troublesome, as it occupied the stoves frequently when new powder was required to be dried; and, as 36 hours' drying could be given without extra inconvenience, the time of drying was increased on 1st April, 1872, from 24 to 36 hours, at the old temperature of 125° Fah. The following are some of the proofs :—

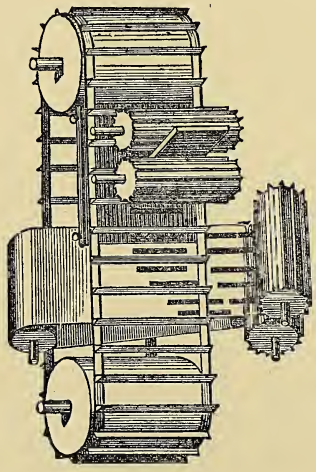
Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
12. 4. 72.....	1·756	19. 4. 72	815	1428	17·6	18·2	16·3
22. 4. 72.....	1·752	26. 4. 72	923	1455	21·8	21·8	19·6
10. 5. 72.....	1·772	17. 5. 72	937	1408	15·2	15·3	14·8
Do., re-dried...	—	29. 5. 72	1002	1507	21·6	21·2	17·7
13. 5. 72.....	1·777	17. 5. 72	940	1452	15·3	14·9	14·1

The last shows a considerable inprovement over the others, being due to a great extent to the fact that a sifting apparatus, of the nature described, was now erected on the machine, so as to sift the pebbles rather severely, by taking out all the small and flakey specimens. This materially reduced the per-centage of finished pebbles obtained from it; that, however, is not to be considered in comparison to the improvement produced in the powder.

The author had all along been favourable to the principle of the other machine, proposed by Captain Smith, and had for some time, after a good deal of trouble and contrivance, got a design ready by which the strips could be conveyed from the first to the second pair of rollers. When Colonel Younghusband found, therefore, that the per-centage of pebbles produced with his machine was only about 60 per cent., he ordered an experimental machine to be made according to this design. Fig. 8 will show its working.

It will be observed that the difficulty consists in conveying the strips, which fall in regular succession, from the first to the second pair of rollers, so that they not only shall not inconvenience each other, but also shall change their direction from moving sideways to a motion endways. This is accomplished by allowing the strips to fall upon a board, over which a succession of strips of wood are moving sideways, and scraping along the surface. Each strip falls into a space between two strips of wood, and is carried sideways along the board. When the first strip gets to the end of the board, it drops over on to a band passing below in a direction at right angles, and is thus conveyed endways to the second pair of rollers. It is manifest, if the board remain stationary, the second strip will drop over on to the top of the first before it has time to clear out of the way. To prevent this, the board is made to move backwards so that the second strip, instead of falling on to the top of the first, falls alongside it, and slightly in arrear, and so on with the next and the next, till the board has moved as far back as can be allowed. The direction of the board is then suddenly changed, and it moves

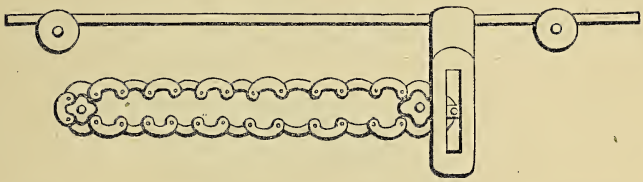
Fig. 8. Scale $\frac{1}{30}$.



forward in the direction of the strips of wood and at the same rate, so as to form a false bottom to the compartments which contain the strips of powder. When

the board has arrived again at the original position, it again suddenly changes its direction, and the motion proceeds as before. The method of changing the direction of the board is by attaching it to an endless chain which passes over two small pulleys. In this manner the direction is reversed every time of passing over a pulley thus:—

FIG. 9. Scale $\frac{1}{8}$.



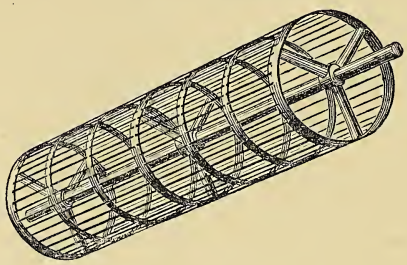
It will be observed in the last samples of firing given, that the density has increased. Of course it was at once apparent, if the fault of low velocity was due to the moisture, there was no need to attempt to meet the case by working to the low limits of density, and the density was therefore increased. It was found, too, that even 36 hours' drying at 125° Fah. was not sufficient, and on the 1st June the temperature of the stove was increased to 135° Fah., for 36 hours, with the following result. The moistures are given at the same time to serve as a guide, if possible, to what may be expected at proof:—

Stoving.	Density.	Moisture.	No. of pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
4. 6. 72	1·781	—	—	12. 6. 72	1034	1450	16·4	16·8	16·0
1. 7. 72	1·780	—	—	12. 7. 72	1109	1465	18·2	18·9	17·9
6. 8. 72	1·784	·93	—	15. 8. 72	1260	1447	17·5	19·2	16·8
21. 8. 72	1·781	1·03	—	13. 9. 72	2	1493	20·8	19·8	18·0
2. 9. 72	1·779	·9	—	4. 10. 72	37	1494	19·7	18·7	17·1
3. 9. 72	—	—	—	4. 10. 72	39	1492	17·1	15·9	16·4
1. 10. 72	1·777	1·44	80	9. 10. 72	63	1491	18·3	17·4	17·1
4. 11. 72	1·782	1·38	80	8. 11. 72	110	1452	16·4	16·4	16·1
22. 11. 72	1·781	1·57	70	2. 12. 75	143	1494	18·5	18·8	18·0
4. 12. 72	1·779	1·34	72	13. 12. 72	170	1475	18·6	16·2	16·9
14. 12. 72	1·772	1·33	76	24. 12. 72	187	1541	19·7	19·1	19·4

This brings down the manufacture to the end of 1872, and it will be admitted there is a considerable improvement on the state of matters which obtained a year before. Not only has the velocity been very much increased, but the pressures have been very considerably reduced. This latter point is mainly due to the increase in the size of the pebbles. Instead of being about 140 to a pound, they are now between 70 and 80, as shown by the column of figures. It will be observed that, with the introduction of a new proof gun, there is a considerable rise in the average velocity. This is, no doubt, due to the fact that in the old gun the velocity had fallen off by the wear of the bore. It is not possible exactly to say how much, but evidently it is some 30 or 40 feet in 1200 rounds. Stoving 3. 9. 72 is the first sample with the machine described, as worked out by the author on Captain Smith's principle. It not only gave much better pebbles, but a much larger percentage—about 80 per cent. This machine has ever since continued in constant operation without mishap, and has done the greatest amount of the work of granulation or pebble-cutting. The sifting arrangement in use with

Colonel Younghusband's machine was an ordinary shaking screen, but it was found that the mesh for taking out the small and flakey pebbles was apt to choke up and interfere with its proper action. One of the foremen of the Machinery Department suggested that a reel would be more suitable. This was applied to the new machine with the oblong mesh described, and has been found to work very satisfactorily. A reel of the same sort is now being fitted to Colonel Younghusband's machine. The following figure will give an idea of this reel:—

Fig. 10. Scale $\frac{1}{30}$.



Before closing the work of 1872, the following samples of the firing of mixtures of Waltham Abbey powder may be given to show how satisfactorily the system of mixing has worked.

The hopper described was brought into operation in January 1872, and the following are some of the mixtures made with it:—

Brand.	Stoving.	Density.	No. of barrels.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
127...	23. 1. 72	1·760	51	—	755	1470	18·9	19·2	17.1
	19. 2. 72	1·753	127	—	738	1397	16·0	16·0	14·8
	26. 2. 72	1·749	62	—	774	1462	19·0	18·2	17·6
		Mean...	...	.....	...	1432	17·4	17·3	16·0
No. 127	.....	...	240	13. 3. 72	795	1432	17·4	16·7	15·6
137 ...	2. 4. 72	1·737	44	12. 4. 72	905	1461	21·1	20·5	18·5
	3. 4. 72	1·768	48	12. 4. 72	906	1396	17·5	17·9	16·2
	4. 4. 72	1·753	46	12. 4. 72	907	1432	17·2	16·8	15·8
	8. 4. 72	1·758	48	12. 4. 72	911	1452	20·1	19·4	18·9
		Mean...	...	.....	...	1434	19·0	18·6	17·5
No. 137	.....	...	186	19. 4. 72	916	1429	18·6	18·3	17·0
153 ...	10. 4. 72	1·736	45	19. 4. 72	913	1465	21·0	20·0	17·9
	29. 4. 72	1·751	47	10. 5. 72	929	1464	21·3	20·8	18·6
	15. 5. 72	1·782	47	23. 5. 72	976	1403	13·2	12·9	12·4
	16. 5. 72	1·785	48	23. 5. 72	977	1405	15·1	14·8	13·9
		Mean...	...	.....	...	1434	17·6	17·1	15·7
No. 153	.....	...	187	6. 6. 72	1018	1437	17·4	17·1	15·5
224 ...	29. 8. 72	1·764	43	13. 9. 72	11	1514	20·4	18·0	18·0
	31. 10. 72	1·774	47	8. 11. 72	108	1433	14·9	15·0	14·9
		Mean...	...	.....	...	1471	17·5	16·4	16·3
No. 224	.....	...	90	13. 12. 72	164	1472	17·1	16·6	16·9
225 ...	31. 8. 72	1·776	43	13. 9. 72	13	1539	22·0	20·9	20·0
	1. 11. 72	1·796	46	8. 11. 72	109	1416	13·6	13·8	14·2
		Mean...	...	.....	...	1480	18·2	17·6	17·3
No. 225	.....	...	89	13. 12. 72	165	1469	17·9	16·8	17·4

These are some of the results which are calculated to delight the heart of a powder-maker, and prove that a patient continuance in well doing is sure to be rewarded. It may be taken for granted that not only is the mechanical system of mixing in use at Waltham Abbey a perfect success, but that the method of testing the powder is not only consistent with itself, but calculated to produce one of the prime requisites of good powder—viz., uniformity of results.

A system of mixing powder similar to that just described, is in use at Wetteren, though at first it was not quite so perfect as the plan at Waltham Abbey. At Wetteren, the powder when finished is stored in large bins, and when a batch of powder has to be made up for shipment a small portion is taken from each bin for every barrel. Were the bins uniform, this system would be perfect. Of late, attention has been given to insure uniformity of the powder in the bins, somewhat after the plan at Waltham Abbey. The following proofs are given of Wetteren powder :—

Lot.	Density.	Moisture.	Experiment.		M.V.	Pressures.		
			Date.	No.		A.	B.	C.
45	1·773	1·17	7. 12. 72	151	1427	17·5	15·8	15·1
46	1·766	1·17	"	152	1435	16·7	17·6	16·1
47	1·766	1·17	"	153	1452	17·2	17·0	16·4
48	1·771	1·17	"	154	1440	16·5	16·2	16·1
49	1·771	1·21	"	155	1416	15·6	15·6	15·2
50	1·775	1·13	"	156	1406	14·9	14·3	14·5
51	1·771	1·17	"	157	1438	16·2	17·5	15·3
52	1·773	1·20	"	158	1432	15·8	15·5	15·5

That to produce uniform powder is by no means an easy matter, the proof of the following lots of pebble supplied by Messrs. John Hall and Son will show :—

Lot.	Experiment.		M.V.	Pressures.		
	Date.	No.		A.	B.	C.
1388 ...	7. 3. 72	785	1414	15·2	15·1	13·8
		787	1442	16·5	17·2	16·3
		790	1481	25·9	21·6	20·5
1399 ...	13. 3. 72	802	1496	16·5	16·5	15·8
		803	1432	12·3	13·2	13·1
		808	1386	11·2	10·4	11·2

These samples are not given to show any inferiority of manufacture by Messrs. Hall and Son, but simply to illustrate the variations powder is capable of exhibiting, even when the manufacturers may be satisfied as to its uniformity. Messrs. Hall and Son were unfortunate in their first attempts to manufacture pebble, but they afterwards succeeded to a degree that has not left them inferior to any of the other manufacturers.* The powder supplied by them, as a rule, exhibits low pressures in comparison with the velocities. Their powder is cut on the principle in use at Waltham Abbey, but the machinery is different. They pass the cakes through the same sort of cutting

* The following proofs of Messrs. Hall and Son's more recent manufacture will show the im-

rollers or through a guillotine machine. In order to convey the cakes from the first to the second cutters, they press each cake between two sheets of canvas. These sheets of canvas hold the strips together after passing the first cutters. The whole cake is in this state turned by hand through a quarter circle and passed through the second pair. This plan is rather more troublesome and expensive than that at Waltham Abbey, but it is equally efficacious.

The Kames Gunpowder Company also at first experienced considerable difficulty in producing good pebble, as the following proofs will show:—

Dates of proof, 19th and 20th March, 1872.

Lot.	Samples.	Experiment.	M. V.	
71	1 and 2	846–7	1355	1372
72	"	848–9	1367	1369
73	"	850–1	1376	1360
76	"	844–5	1408	1394
77	"	853–4	1403	1389
78	"	855–6	1383	1395
79	"	857–8	1361	1373
80	"	859–60	1365	1378
81	"	861–2	1373	1372

The difficulty at Kames at this period was to get sufficient velocity, and it was not till after a visit had been paid to Waltham Abbey that they succeeded in meeting the specification. In their opinion the powder they afterwards made, and which readily passed the specification, was inferior to that of which the proof has been given; by which is to be understood that it was not so thoroughly incorporated. Further on will be given some experiments made at Waltham Abbey which confirm this opinion.

Messrs. Curtis and Harvey supplied two sorts of powder—one, as already stated, broken up by the ordinary granulating machine, the other consisting of pressed pellets, afterwards broken in two. The latter powder was found to give very good results when fired, as shown in the following proofs:—

Lot.	Experiment.		M. V.	Pressures.		
	Date.	No.		A.	B.	C.
1404 ...	30. 11. 71	424	1450	15·4	16·4	15·7
		425	1440	16·1	15·7	14·0
		426	1438	13·3	14·3	14·1
1470 ...	15. 3. 72	823	1422	18·1	17·3	17·2
		824	1424	17·2	17·6	16·7

provements made. The uniformity of results is due to their having adopted a mechanical system of mixing:—

Lot.	Date of experiment.	Corrected M. V.	Corrected pressures.		
			A.	B.	C.
A	16.10.74	1451	15·5	14·9	13·6
B	"	1465	16·1	15·5	15·3
C	"	1444	15·9	14·7	14·9
D	"	1444	15·2	14·9	14·5
E	"	1454	14·5	13·8	13·2
G	"	1447	15·2	14·9	14·0
I	"	1448	15·6	15·3	14·6
K	"	1448	15·0	15·2	13·9
M	"	1476	17·8	17·8	17·3

None of the whole pellets, whether made by the trade or at Waltham Abbey, have ever succeeded in giving results at proof equal to those obtained with pebble, and it seems strange that the simple fact of splitting them in two should have such a beneficial effect. The reason is pretty well understood to be that pressed surfaces are not so readily or regularly inflammable as broken surfaces. The mere fact, therefore, of splitting the pellets furnishes two broken surfaces which they would not otherwise possess.

The following proofs of Curtis and Harvey's pebble show that though, as a rule, their powder is very uniform, they could not at this time always supply the same sort.*

Lot.	Experiment.		M. V.
	Date.	No.	
1492	16. 9. 72	17 and 18	1452 and 1467
1493	"	19 " 20	1483 " 1498
1494	"	21 " 22	1502 " 1499
1495	9. 10. 72	55 " 56	1492 " 1495
1496	17. 10. 72	76 " 77	1415 " 1408
1497	"	78 " 79	1414 " 1407
1498	"	80 " 81	1466 " 1454

Messrs. Pigou and Wilks had considerable success in meeting the requirements of proof as regards velocity and pressure. The following samples of proof are given:—

Lot.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
876.....	1·758	3. 1. 72	525	1458	18·3	18·5	15·7
	1·776	"	526	1445	17·1	16·8	15·6
	1·789	"	527	1453	18·4	17·3	15·6
911.....	1·759	5. 3. 72	769	1463	19·4	19·6	17·7
	1·782	"	770	1425	14·4	14·4	14·4
	1·763	"	772	1431	17·2	16·4	16·2
934.....	1·788	12. 6. 72	1044	1435	16·8	17·0	15·6
	1·774	"	1045	1446	18·4	18·1	16·7

From what has been said, it will be seen that the manufacture and proof of pebble-powder had very greatly improved during 1872. Density, velocity,

* The following proofs of Curtis and Harvey's more recent manufacture show a very remarkable uniformity:—

Lot.	Date of experiment.	Corrected M. V.	Corrected pressures.		
			A.	B.	C.
A.	17. 8. 74.	1476	17·6	17·2	16·7
B.	"	1474	17·5	18·1	16·2
C.	"	1471	16·6	16·6	16·8
D.	"	1450	16·4	16·2	15·7
E.	"	1464	17·6	16·8	15·8
F.	"	1471	17·3	17·1	15·3
G.	"	1478	18·0	17·7	15·9
H.	5. 10. 74	1475	16·7	15·7	15·8
I.	"	1467	17·3	16·3	16·7
K.	"	1470	15·7	16·3	16·0
L.	"	1467	16·3	16·8	15·6
M.	"	1463	16·3	16·5	16·0

and size of grain had all increased, and pressure had materially diminished. The importance of velocity and low pressure need not be explained, but it may be stated that increase of density is an advantage, not only in improving the keeping qualities of the powder, but also in making it pack into smaller bulk, and that increase of size of grain appears to be the best known cause for facilitating the uniform ignition of the whole charge, and thus preventing those wave pressures which occur with smaller-grain powder, and which are so very detrimental to the projectiles and powder-chambers of the guns. Other things being equal, the larger the grains that can be used, the larger the charges which can be employed with advantage.

It will be noticed also that, instead of the year closing, as did 1871, with low velocities, the difficulty is now to keep down the velocity. The beginning of 1873 shows no alteration in this respect, as the following new year's gift will prove:—

Stoving.	Density.	Moisture.	Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
1. 1. 73	1·781	1·2	72	9. 7. 73	219	1530	22·4	22·4	21·3

Colonel Younghusband tried some experiments in order, if possible, to bring down the velocity, without leaving an undue amount of moisture in the powder. The first means of doing so that naturally occurs to a powder-maker is to dispense, to some extent, with the most important of all the operations —namely, milling. Four samples of shorter-milled powder were accordingly made in different mills and under different circumstances.

They were made from the charcoal then in use, pressed as usual 15⅛ ins., and dried 36 hours at 135° Fah. The following is the result of proof:—

Stoving.	Density.	Moisture.	Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
3. 1. 73 A.	1·771	1·08	70	9. 1. 73	221	1532	24·6	24·0	22·8
" B.	1·761	1·05	70	"	222	1538	25·4	25·1	22·9
" C.	1·768	1·01	76	"	223	1538	25·7	26·0	25·1
" D.	1·759	1·05	66	"	224	1538	24·3	23·2	21·6

It will be observed that the density is low as compared with powder then manufactured, and also that the moisture shows the powder to be dry. The experiment was therefore repeated with powder pressed rather more—15¼ ins.—and dried 36 hours at 125° Fah.:—

Stoving.	Density.	Moisture.	Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
25. 1. 73 A_1	1·782	1·08	72	3. 2. 73	267	1520	21·6	21·6	20·0
" B_1	1·777	1·04	72	"	268	1535	21·8	21·6	20·2
" C_1	1·789	·95	74	"	269	1535	23·3	22·4	21·1
" D_1	1·786	·9	72	"	273	1541	22·1	22·3	20·4

There is some improvement in the pressures, but evidently not much in the velocity. The experiment was again repeated with charcoal more highly charred—a well-recognised method of reducing the violence of gunpowder. The samples were pressed 15⅜ ins., and stoved as in the last case:—

Stoving.	Density.	Moisture.	Pebbles to 1 lb.	Experiments.		M.V.	Pressures.		
				Date.	No.		A.	B.	C.
8. 2. 73 A_2	1·759	1·1	78	19. 2. 73	313	1539	25·5	24·5	22·4
" B_2	1·759	1·08	76	"	314	1533	21·7	21·2	20·7
" C_2	1·759	1·3	78	"	315	1507	19·7	18·5	18·1
" D_2	1·759	·9	76	"	316	1541	24·4	23·3	22·6

Evidently there is no improvement yet, but four other samples were tried made with ordinary charcoal, pressed still more—15½ ins.—and stoved only 24 hours at 125°, with the following results:—

Stoving.	Density.	Moisture.	Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
6. 3. 73 A_2	1·795	1·26	80	14. 3. 73	413	1405	14·4	14·3	14·6
" B_2	1·790	1·22	80	"	414	1408	14·2	14·8	12·7
" C_2	1·790	1·30	70	"	415	1393	13·2	13·2	13·0
" D_2	1·788	1·22	74	"	416	1383	11·7	11·6	12·0

These samples are given at some length, because it was now that the author fancied he saw into the secret recesses of pebble-powder and its mode of action. The whole question seems to lie in the porosity of the grains. The more porous the grains, the more violent will be the action. It is a case exactly similar to that of large interstices in large charges. If the grains be large it matters little if they be porous, for the pressure of the gas in the powder-chamber will force the flame into the very heart of the grains; and hence the very violent action of $2A_4$ powder. Now, it follows that anything which adds to, or takes from, the porosity of the grains during manufacture will have a corresponding effect at proof. It is a very remarkable fact that, as summer advances, the tendency, both with large and small-grain powders, is for the density to increase. The presses have to be continually altered so as to press less and less in order to give the required density. No doubt this is due to the fact that the incorporating or milling is more perfect in summer than in winter—a fact well known to manufacturers.

The more milling the powder receives, the more pasty it becomes—so much so, that with fine-grain powder, where long milling is used, the powder on the beds of the mills has a tendency to adhere to the runners. This pastiness has the effect of rendering the powder more compact and easily pressed. The opposite effect, of course, takes place with shorter milled powder. It will not press so close together, and will be less dense and more porous than powder longer milled.* This accounts for the low densities of the 3. 1. 73

* The author has quite recently been informed by Mr. Haycraft, of Messrs. Hall and Son's, that he has lately had a remarkable confirmation of the truth of the statement made in the text. As the summer advanced, he found it constantly necessary to press the powder less and less, and even by so doing he failed to bring down the density. It was only by reducing the milling that he succeeded in restoring equilibrium.

samples. It also accounts for their more than usual dryness; for if the powder be porous, the more readily will it part with its moisture.

The same remark applies to 25. 1. 73 samples; for evidently both sets have been dried sufficiently, and part of the moisture is to be regarded as what the powder has re-absorbed after stoving. The 3. 1. 73 samples being less dense, though they have been more dried at first, may, at the time of being tested for moisture, have absorbed more moisture than the 25. 1. 73 samples, which are denser. The amount of moisture, however, in powder gives very little idea of what may be expected at proof. This had long been known, and a very short inspection of the samples already given will show that this is the case. The reason of this, however, was now capable of being explained; for evidently the powder must dry from the surface to the centre, and probably in the centre of each grain there is a considerable portion which receives little drying. The average amount of moisture will therefore be determined by the amount which was in the powder before stoving, and will give but little idea of the amount of dryness of the outer portions of the pebbles, which have the most important effects on the proof.

The 8. 2. 73 samples admit of ready explanation on the same principles. Though more pressed, the density is again lower. The grains of charcoal, being harder, will still more refuse to incorporate, and will make the powder more brittle and less pasty, which will manifest itself in the density at pressing.

The 6. 3. 73 samples show the old tendency to low velocities. Comparing, however, these samples with powder made at the same period in 1871 and 1872, which was dried the same amount, it appears that the densities then were less, and consequently the rule still holds good.

With fine-grain powder, long milling and slack-burned charcoal increase the velocity obtained at proof, but with pebble the reverse holds good; and here we have an exact parallel to the case of fine-grain and large-grain powder in large charges. With fine-grain powder in small charges, the charcoal probably has not time to seek its oxygen unless it be brought very intimately in contact with it; but in large charges, where the time of explosion is necessarily much longer, owing to increased resistance of the shot, time is not so much an object, and the great heat may release the oxygen much more effectually and rapidly. It is probable also that each small particle of charcoal may require a certain time to burn, and there may be ample time in large charges, but not in small charges unless the particles are pulverised considerably by long milling. It is well known that a "mixed charge" will only just flare up if fired in a small quantity, but if it be fired in bulk the result is an explosion. This explains the observation made with regard to the Kames pebble; for if that firm over-milled their powder with the idea of getting up the velocity, from what has been said it will be seen that it would produce the opposite effect.

Another observation may be made with regard to the manufacture of pebble-powder bearing on the same point. Powder when incorporated in the mills usually has a certain per-centage of moisture in the charge with a view of aiding the incorporation. Fine-grain powder is usually worked with about 3 per cent. of moisture, but pebble with from $3\frac{1}{2}$ to 6 per cent. An explosion of fine-grain powder with 3 per cent. of moisture is very violent, and generally destroys the building; but, with pebble-powder and 5 or 6 per

cent. of moisture, the explosion does little or no damage. It is, therefore, a great advantage to work with as much moisture as possible. Some have thought that the more moisture in the powder when milled and pressed, the more moderate will be the results of proof, and that this is due to a sort of hard and crystalline texture which the powder thus assumes. The author does not believe in this theory, and certainly the results of proof do not bear it out. It is true no doubt that powder if too dry will not pack well together, even if pressed with a very high pressure; and this was found to be the case in the earlier experiments to obtain powder for heavy guns, when the Doremus pellets, which were pressed with as much as three tons to the inch, were found to be very violent even in field guns. A certain amount of moisture must therefore be in the powder when milled and pressed, in order to make it pack together; but if this amount is exceeded, the results are prejudicial, and, with pebble-powder, instead of mitigating the violence, rather increase it. No doubt, if the powder be not properly dried, the moisture has a moderating tendency, and probably this is the reason which has given rise to the crystalline theory. If, however, the powder be thoroughly dried, it has always been found that with moisture over a certain per-centage—about 4½ or 5 per cent.—it is much more difficult to get a high density. No doubt this and the more violent action at proof are caused by the moisture, in forcing its way from the interior of the pebbles, forming porous channels, which not only swell the powder, but also leave passages for the flame to penetrate more readily into the interior. If too much moisture be in the powder when pressed, the water can be seen to be squeezed out, showing that the extra amount can produce no good effects, and must, if confined, prevent a high density being obtained.

The great difficulty of getting the moisture from the interior of the pebbles, as has been stated, is another reason why too much moisture should not be used. In making these observations, however, the author begs to observe that they are entirely his own views, and are not necessarily accepted by everyone.

A remark may, however, be made to which all that has been said seems naturally to tend—namely, that to produce a powder which shall be moderate in its action is both troublesome and expensive, unless an undue amount of moisture be admitted; but a powder can be produced safely, expeditiously, and economically, which, though somewhat violent in its action, does not give an exceptionally high pressure in comparison with the velocity. If the guns will stand, no difficulty will be found in providing a powder capable of giving the very best results.

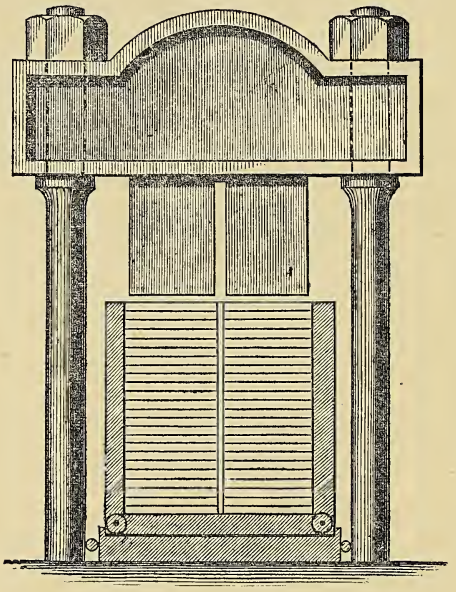
The manufacture of pebble has been carried on in 1873 and 1874 much in the same manner. The variations of the seasons have to be studied, and, as a rule, it has been found that density is more easily obtained in summer than in winter, owing to the more effectual incorporation. The amount of milling has been reduced, as it appears unadvisable to prolong this operation—which is the most dangerous of all—more than is absolutely necessary.

The press-boxes at Waltham Abbey produce cakes of powder 30 ins. square, which are not only too large to pass through the pebble machine, but the size of the copper plates between the cakes allows the plates to buckle, and so produces cakes of uneven thickness. The perfect action of the machine depends to a great extent on the uniform thickness of the cakes, otherwise the long

strips are broken up into short pieces. A plan of remedying this defect, suggested by the Assistant Chief Foreman of machinery, was carried out during 1873. It consists in dividing the press-box and block into two, so that the cakes produced are only of half the width, and suitable at once to pass through the pebble machine without being broken up.

The following figure shows the method adopted.

Fig. 11. Scale $\frac{1}{30}$.



Care, however, must be taken after the cakes are pressed to keep them from buckling, which they will readily do when first pressed.

A large amount of L.G. powder has been re-worked into pebble. The following are the first proofs of this powder, which was made from Curtis and Harvey's L.G. powder. The drying was 38 hours at 127° Fah.

Stoving.	Density.	Moisture.	Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
14. 7. 73	1·806	1·27	74	29. 7. 73	682	1415	13·5	13·2	13·8
15. 7. 73	1·803	1·48	74	"	683	1409	13·2	12·9	13·0
17. 7. 73	1·803	1·28	76	"	684	1356	11·6	11·2	10·3
18. 7. 73	1·804	1·41	—	"	685	1419	13·2	13·2	13.3

These stovings were mixed and re-dried, and again proved.

Experiment.		M. V.	Pressures.		
Date.	No.		A.	B.	C.
15. 8. 73	697	1454	14·4	14·7	14·2

This is most excellent powder, and it will be observed that the density is high and the powder consequently difficult to dry.

The following are proofs of pebble re-worked from Hall and Son's L.G. :—

Stoving.	Density.	Moisture.	No. of pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
28. 11. 73 1. 12. 73	1·789 1·797	1·20 1·11	76 76	8. 12. 73	785	1432	14·8	15·0	14·6
9. 12. 73 10. 12. 73	1·792 1·796	1·37 1·07	76 82	15. 12. 73	790	1454	15·9	15·6	15·1

These stovings were dried 36 hours at 127°.

At this time, and for some months previously, it was the *rule* to prove double stovings instead of proving each separately, and this is attended with no inconvenience; for even if a double stoving fails, there is still opportunity in the four-way hopper of mixing it with another double stoving of an opposite character.

It will be seen that the question of stoving is a very important one. What is required is to give the powder that amount of stoving which will leave it in a normal condition as regards moisture, so that afterwards the velocity shall not be affected. In order to obtain some data on this point, 10 barrels were dried 72 hours at 125° Fah. and fired once a month.

Stoving.	Density.	Moisture.	Experiment.		M. V.	Pressures.			Corrected			
									M. V.	Pressures.		
			Date.	No.		A.	B.	C.		A.	B.	C.
31. 5. 72	1·773	·77	12. 6. 72	1038	1502	20·4	19·8	18 8	—	—	—	—
"	"	—	12. 7. 72	1107	1490	19·3	19·5	18·6	—	—	—	—
"	"	—	7. 8. 72	1157	1473	19·3	18·4	16·5	—	—	—	—
"	"	—	13. 9. 72	7	1515	22·6	22·4	19·4	—	—	—	—
"	"	—	9. 10. 72	57	1520	20·4	19·0	18·9	1523	20·4	19·0	18·9
"	"	1·28	18. 11. 72	121	1501	18·2	18·2	17·1	1507	18·3	18·3	17·2
"	"	1·17	13. 12. 72	166	1499	19·4	19·2	17·4	1507	19·5	19·3	17·5
"	"	1·33	9. 1. 73	225	1511	19·5	20·0	19·3	1522	19·7	20·2	19·5
"	"	1·38	10. 2. 73	297	1486	17·9	17·5	17·8	1501	18·2	17·8	18·1
"	"	1·35	12. 3. 73	398	1486	19·3	18·3	17·4	1506	19·7	18·7	17·8
"	"	1·30	10. 4. 73	501	1474	16·8	16·6	16·5	1499	17·3	17·1	17·0
"	"	1·16	14. 5. 73	544	1495	18·3	18·9	17·8	1522	18·8	19·4	18·3
"	"	1·3	19. 6. 73	603	1493	19·8	19·7	18·2	1523	20·4	20·3	18·8
"	"	·95	15. 7. 73	657	1485	18·9	18·5	17·5	1518	19·5	19·1	18·1
"	"	1·11	15. 8. 73	698	1485	21·1	20·5	18·6	1520	21·8	21·2	19·3
"	"	1·21	19. 9. 73	732	1458	18·5	17·9	17·0	1495	19·2	18·6	17·7
"	"	1·44	17. 10. 73	746	1476	17·5	17·9	17·0	1513	18·2	18·6	17·7
"	"	1·41	14. 11. 73	769	1452	16·6	16·3	15·4	1490	17·3	17·0	16·1
"	"	1·34	15. 12. 73	788	1470	17·8	17·2	15·9	1509	18·6	18·0	16·7
"	"	1·18	12. 1. 74	801	1483	18·1	17·9	16·3	1523	18·9	18·7	17·1
"	"	1·20	13. 2. 74	106	1507	18·1	18·9	18·3	1512	18·2	19·0	18·4
"	"	1·15	20. 3. 74	847	1426	15·3	14·7	15·1	1468	16·1	15·5	15·9
"	"	1·0	20. 4. 74	875	1456	18·0	17·1	17·0	1500	18·8	17·9	17·8
"	"	1·0	21. 5. 74	144	1495	20·3	19·5	19·3	1502	20·4	19·6	19·4
"	"	1·15	1. 7. 74	176	1508	20·8	20·2	18·1	1516	21·0	20·4	18·3
"	"	1·0	17. 7. 74	188	1570	20·3	20·5	16·9	1519	20·5	20·7	17·1
"	"	1·1	17. 8. 74	206	1517	20·6	20·3	19·4	1527	20·8	20·5	19·6
"	"	1·18	16. 9. 74	244	1513	20·5	20·2	19·1	1525	20·7	20·4	19·3
"	"	1·28	23. 10. 74	297	1497	18·4	20·2	18·3	1511	18·7	20·5	18·6
"	"	1·0	19. 11. 74	309	1481	19·3	19·3	18·5	1496	19·6	19·6	18·8
"	"	1·15	7. 12. 74	321	1479	18·6	18·9	17·1	1495	18·9	19·2	17·4

It will be observed in the additional columns for velocities and pressures,

that corrections have been made for the wear of the bore of the proof gun. These were obtained by firing identical samples from two proof guns—one new and the other worn.

Stovings.	Density.	Moisture.	Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
9. 8. 73	1·777	·94	80	21. 8. 73	706	1498	20·3	20·3	17·7
					4	1537	20·6	20·3	18·7
11. 8. 73	1·787	·99	70	"	707	1467	18·1	17·8	17·5
					5	1508	19·1	18·4	17·5
12. 8. 73	1·787	1·14	74	"	708	1459	16·5	16·5	16·1
					6	1486	17·0	16·9	16·7
21. 8. 73	1·799	·99	64	3. 9. 73	726	1433	16·0	15·7	14·6
					16	1470	17·6	16·6	16·4
27. 8. 73	1·785	1·11	64	"	727	1441	14·9	14·8	15·7
					17	1478	16·5	16·5	16·5
23, 25 8. 73	1·793	1·04	66	"	725	1434	15·1	14·4	13·6
					15	1470	15·8	16·1	15·0
24, 25 2. 74	1·808	1·41	77	9. 3. 74	825	1419	16·4	16·1	15·5
					110	1450	16·8	15·9	16·5
25, 27 2. 74	1·804	1·37	78	"	826	1399	17·4	16·5	14·8
					111	1439	16·6	16·3	15·2
26, 27 2. 74	1·779	1·05	77	"	827	1484	22·3	22·1	20·2
					112	1535	22·8	23·1	21·9

From these experiments it is concluded that about 5 ft. must be added for 100 rounds to reduce the velocity to that of a new gun, and about 2 cwts. for each 100 rounds for pressure. The corrections are not shown in the old gun in use in 1872, as that gun as a rule fired much less violent powder, and the corrections would probably be $\frac{1}{3}$rd less. If we neglect the sample fired 13. 9. 72, where the pressures are evidently exceptionally high, it will be observed that the powder at first loses in velocity and pressure from its having been overdried, but that afterwards it does not materially lose its velocity or pressure when it once has reached a normal state of moisture, as it may be supposed to have done in November, 1872.

Some experiments have been made by Colonel Younghusband as to the time required to dry powder of large size of grain. The samples chosen were inch cubes, and the specimens were dried whole and compared with similar specimens broken up to a size rather larger than R.L.G. with the following result:—

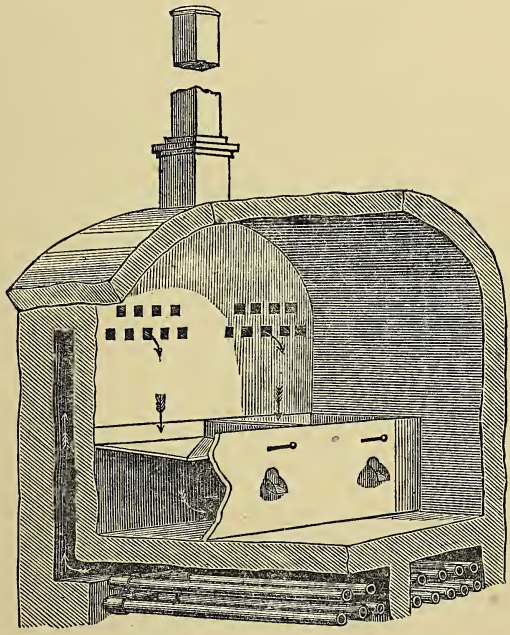
No. of hours dried at 160° Fah.	Loss of moisture in inch cubes.						
	Waltham Abbey.		Hall and Son.				
	Density 1·792.		Density 1·82.				Density 1·75.
			A.		B.		C.
	Whole.	Broken up.	Whole.	Broken up.	Whole.	Broken up.	Whole.
24	·284	1·103	·237	1·062	·290	1·312	·308
48	·464	1·103	·402	1·194	·501	1·527	·484
72	·490	1·103	·568	1·261	·712	1·527	·625
96	·594	1·103	·663	1·261	·817	1·527	·659
120	·619	1·103	·710	1·261	·897	1·527	·659
144	·645	1·103	·805	1·261	·976	1·527	·681
168	·697	1·103	·876	1·261	1·108	1·527	·703
192	·800	1·103	·947	1·261	1·134	1·527	·703
216	·800	1·103	·971	1·261	1·213	1·527	·703

The question of the best method of drying powder has received some attention of late at Waltham Abbey, and in order to gain some information to aid in the construction of a new stove, an experimental stove was built of 8 ft. square internal floor and about 10 ft. high. Colonel Younghusband wished to have the hot air pass from above downwards, as that is evidently the best method of drying, and is used in some places where drying is carried on—as at Enfield Lock, for drying wooden stocks. In the stoves in ordinary use at Waltham Abbey it is found that the powder sweats very much during the first 10 or 12 hours, and evidently that there is not sufficient circulation to carry off the moisture. The hot moist air seems at first to rise and get heavy with moisture, and then come down again to the bottom of the stove, circulating only in the stove itself.

But if the hot air come in at the top and descend, it has no tendency to rise again, as it absorbs moisture, cools, and becomes heavy. Evidently also pebble-powder gives special facilities for drying, as the large interstices can be used for making the current of heated air pass through the powder.

The plan adopted, therefore, was to make the current pass down through a thick layer of the powder, which for this purpose was placed in bins. No other passage was allowed for the air. An idea of this stove will be obtained from the following figure :—

Fig. 12. Scale $\frac{1}{80}$.



It will be observed that the pipes have been placed underneath the stove. The object of this is to ensure circulation. Hot air tends always to rise, as water tends to fall. But as water will always when confined in any case rise to its original level, so the author conceived hot air when confined to a

passage will always force its way down to its own level. If an outlet, therefore, be allowed for the hot air from the bottom of the stove, a continual current ought to be established. The outlet, however, was led into a flue, so as further to increase the draught.

From some cause or other a sufficient current was not established until the flue was increased by a wooden continuation; but when this was added it was found, when at work, that the draught was sufficient to draw so great a quantity of air through the stove as to bring down the temperature. The temperature could be raised by diminishing the opening by which the external air was admitted to the steam-pipes to become heated. The best plan would be to bring the outlet into communication with some arrangement which would produce a partial vacuum, such as a steam jet; for a vacuum is a well-known method of drying. Thus the temperature might be lowered in the stove with advantage to the drying of the powder—a low temperature and sufficient current of air being the best plan of drying.

This paper may be concluded by giving a few samples of powder fired in the 35-ton gun, by way of experiment, to see what powder is likely to be most suitable. The following rounds were fired with 110 lbs. of powder and 700 lbs. projectile.

Description of powder.	Density.	Fired in 35-ton gun.			Fired in 8-in. gun.				
		Muzzle velocity.	Pressures.		No. of round.	Muzzle velocity.	Pressures.		
			A.	C.			A.	B.	C.
W.A. pebble, 22. 4. 73 ...	1·79	1345	23·2	16·6	556	1468	17·9	17·1	16·7
" inch cubes, 23. 4. 73	1·79	1328	21·8	19·2	564	1431	18·2	17·3	16·4
" lot 1970	1·78	1359	23·4	20·7	618	1486	19·5	19·7	18·5
" inch cubes	1·82	926	2·5	broke	800	750	—	—	—
" " "	1·77	not fired			94	1535	21·7	20·5	18·8
" " "	1·75	1352	24·1	19·6	104	1485	17·0	17·3	15·7
" " "	1·73	1368	24·8	22·3	105	1504	18·4	18·8	18·1
" 1¼-inch cubes	1·77	1334	20·7	18·5	95	1469	15·7	15 0	15·5
" " "	1·75	1311	24·1	16·0	96	1425	13·2	13·2	12·6
" " "	1·73	1334	22·5	19·4	98	1456	14·6	14·7	14·2
" 2-inch cubes	1·79	1095	7·5	6·8	—	—	—	—	—
" " "	1·77	1262	18·0	15·1	99	1429	13·5	13·9	—
" " "	1·75	1239	13·4	11·3	100	1367	9·9	9·9	10·2
" " "	1·73	1241	13·6	11·7	101	1371	10·8	10·6	10·8
H. and S. inch cubes, A ...	1·82	1355	19·8	18·2	736	1440	12·8	12·9	13·3
" " B ...	1·82	1376	24·0	22·4	738	1480	11·03	11·7	11·5
" " C ...	1·75	1385	23·8	19·8	1192	1483	17·7	18·6	18·2

It is manifest from these experiments that the rate of combustion of gunpowder is completely under control, and is a mere matter of manufacturing detail. The various causes which conduce to the attainment of any desired result are not, however, so readily determined; for it will be observed that, true to themselves in their apparent inconsistencies, these samples in many cases seem to arrange themselves in exactly the opposite order to what might have been expected. The effect of size of grain is well known, and the theory of each grain burning from surface to centre has often been advanced, and therefore calls for no special remark. It should, however, also be understood that with this theory must be combined a consideration not only of the density

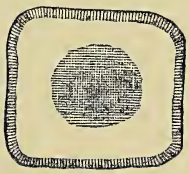
but also of the varying porosity of powder, which allows each grain to burn more or less rapidly according as the density is less or more, and more or less unevenly according to the number and size of the pores.

Porosity and density, though intimately allied, are not necessarily identical; and this helps to a great extent to explain some of the apparent anomalies.

Powder of a density greater than 1·82 or 1·84 *does* burn uniformly; and Captain Castan* says that such powder when picked up unconsumed, after having been fired from guns, shows none of the pit marks which are to be found with powders of less density. These pit marks are doubtless due to the penetration of the flame into the porous channels in the grains, which allow the flame to enter further into the interior than would otherwise be the case, and thus accelerate the combustion. The effect of porosity, however, is mitigated by the amount of moisture the powder may contain, and which, from some cause or other, seems to have an effect on the rapidity of combustion much greater than would be anticipated. Possibly it may generate steam of a tension sufficient to counteract the pressure of the flame. It is not, however, the actual amount of the moisture that affects the rate of combustion so much as the position it occupies. Moisture in the interior of a grain affects the combustion but slightly, but moisture in the exterior moderates considerably the rate of combustion at the period when the effects of greatest importance are produced.

Waltham Abbey inch cubes of high density were thoroughly dried, and the mild character of the sample, 1·82, is to be regarded as entirely due to the high density. It is not to be compared with Messrs. Hall and Son's sample of the same density, which was made with a different charcoal—viz., dogwood, instead of alder. Some of the discrepancies obtained with the other samples, however, are not so easily explained, and the cases where the lower densities gave more moderate results than the higher are probably exceptional; though it possibly may be that the lower densities may have allowed the moisture to penetrate by absorption further into the pebbles, and that each grain was somewhat in a condition which may be represented in the following figure, where the shaded portions represent the moisture :—

Fig. 13. Scale ½.



If such be the case, it is manifest that correct inferences cannot be drawn till the whole grain has reached its normal state of moisture, and that only thus can the relative effects of size of grain and density be fully determined.

Size of grain and density are evidently the two main considerations, and that they to a great extent may be made to compensate for one another

* "Avec les poudres qui dépassent 1·800 de densité, la forme semblable à celle du grain primitif est encore mieux conservée, et la profondeur des alvéoles, diminuant très-notablement, devient à peu près nulle quand on opère sur des densités de 1·840 ou plus."—*Etude des poudres pour le nouveau matériel de l'artillerie de terre, par F. Castan, Capitaine d'Artillerie à la Poudrerie du Bouchet.* 1873.

will appear from the following remarkable result of proof of powder with the 8-in. gun:—

Description of powder.	Density.	Corrected M. V.	Corrected pressures.		
			A.	B.	C.
W.A. pebble, 19-20. 10. 74	1·797	1442	15·9	16·0	15·0
" 2-inch cubes, 9. 6. 74	1·75	1444	16·7	17·0	16·0

The old theory of grains of powder burning uniformly from the surface to the centre would utterly fail to account for such results as these, and even when combined with the density theory it is difficult to give a satisfactory explanation where the densities differ so little. If, however, the porosity of the grains be taken into consideration, the difficulty to a great extent disappears; for when once it is admitted that the flame may burrow itself into the mass of the grain, it becomes a mere question of how far it does so in order to account for a violence of explosion even greater than was exhibited by the $2A_4$ grains referred to in the beginning of this paper.

Another important element in its influence on the rate of combustion of gunpowder, is the nature of the charcoal used. In a great many respects this is very obscure. From an observation of the consistent manner in which the pebble-powder supplied by Messrs. Hall and Son gave low pressures with high velocities, the author was led to infer that the charcoal was the main cause. The density of the powder was low, but Messrs. Hall burn their charcoal rather hard, the effect of which is to make it, when ground, gritty, or more of the nature of fine-grain than dust. Each particle of charcoal must take time to burn, and the larger the particles the slower will be the combustion. This cause more especially affects the initial stages of combustion, where the modification is most required, while the low density gives all the advantage of a quick-burning powder afterwards.

It is thus evident that out of the various methods which are open in powder-making for the purpose of moderating the rate of combustion and rendering it suitable to any size of gun, many choices may be made, so long as the applicability of the powder to the gun is kept in view, and uniformity is secured. The most recent experiments of the Committee on Explosives lead them to infer that cubes of $1\frac{1}{4}$ or $1\frac{1}{2}$ ins. with a density of about 1·75 will prove most suitable; and thus a muzzle velocity of about 1400 f.s. may be obtained with a projectile of 800 lbs. from the 38-ton gun with a pressure of less than 25 tons in the bore of the gun. The following are given as samples—the charge being 130 lbs., and weight of shot 800 lbs.:—

Description of powder.	Density.	Experiment.		M. V.	Pressure in tons per square inch.				
					Axis of bore.	Centre of charge.	Base of shot.	Feet travel.	
		Date.	No.		A.	B.	C.	1.	2.
W.A. $1\frac{1}{4}$-inch cubes, 13. 4. 74	1·75	23. 7. 74	13	1380	22·9	21·6	17·3	19·9	15·6
			14	1380	25·0	24·6	22·7	20·2	16·1
W.A. $1\frac{1}{2}$-inch cubes ..... 26. 8. 74 / 12. 5. 74 mixed 2 to 1...	1·75	3. 12. 74	79	1393	vent	23·7	23·3	19·7	14·2
			81	1386	"	23·6	23·1	19·0	13·6
		30. 12. 74	89	1403	24·3	24·6	22·9	18·7	14·9
			91	1398	22·5	24·3	22·5	20·5	14·7
			92	1406	23·7	22·9	22·6	21·7	—
			93	1414	23·2	23·3	23·3	20·0	—

NOTES

ON

ARTILLERY IN THE FIELD.

BY

LT.-COL. W. J. WILLIAMS, R.A., C.B.

These notes are written with reference to the requirements of European war, and not with any regard to the question, To what extent should the British army in time of peace be constituted by brigades and divisions?

I.

In the British service, there being no equivalent to the infantry regiment of continental armies, we place three or four battalions in a brigade, and we are obliged to place three of these small infantry brigades in a division. It would be better for us to overcome than to be ruled by the difficulty of having no regimental or demi-brigade organisation. With the brigade of six battalions there would be two infantry brigades in a division. There can be no doubt of the advisableness of attaching a regiment of cavalry divisionally to every division. In the last war, the Germans attached a rifle battalion divisionally to the first division of every corps, and the French brigaded a rifle battalion with the first brigade of every division. It would seem to be advisable for us to augment our infantry by attaching a rifle battalion divisionally to every division. A British division then would consist of two infantry brigades, a battalion of rifles, a regiment of cavalry, the artillery, the engineers, and the train.

II.

In the late war, the Germans had four batteries attached to the division and six batteries to the corps, which gave them seven batteries to their division of twelve or thirteen battalions and four squadrons. The cavalry divisions had their own artillery, in the proportion of one battery to sixteen squadrons. The French had three batteries of divisional artillery and two batteries of corps reserve artillery for their divisions of thirteen battalions; their cavalry divisions of corps had no artillery; their reserve cavalry divisions had a battery to every brigade; there was a main artillery reserve of sixteen batteries. Allowing for the difference of strength of the French and

German battalions, the French army had the greater proportion of guns. The British battalion being of the same strength with the German, and it being advisable to give a large proportion of artillery to a small army, there should be eight batteries to a British division of thirteen battalions and four squadrons, besides the artillery attached to cavalry.

III.

It begins to be admitted that the distinction made between divisional and corps or reserve artillery is simply arbitrary. A corps, or a division, may be held in reserve; but when troops are to go into first line all their artillery should go with them, the whole of the guns preceding the mass of the infantry.

Against the present system of attaching artillery, and of directing the operations of artillery in the field through the medium of a commanding officer of artillery who remains near the person of the General, there are certain grave objections. The most important of these is that the system is not the best calculated to provide for the most effectual use of the arm in battle. It would be better to make all artillery divisional, and to brigade the artillery as the third brigade of the division.

IV.

The artillery brigade of a division should consist of two horse and six field batteries. The brigade should be commanded by a Major-General or a Brigadier-General. The commander of the artillery brigade should be with his brigade, and not on the general staff of the division. The commander of the artillery brigade should be eligible for division command.

The present system of directing artillery in the field has been continued down from times when there were few guns with an army, and they could hardly be moved, and the firing of cannon was connected in the general mind with some vague idea of science. It is true that an artillery officer may soar into high mathematics perhaps with profit to his arm, and that artillery has its minor tactics with which the infantry or cavalry General cannot be very familiar; but it is also true that every general officer in command ought to be capable of giving general orders for artillery in quarters, and in the field, and in battle. In reality, artillery is not now protected by the lightest veil of mystery; no officer of high rank is at all afraid of touching artillery. At present the Division General himself commands his artillery, not as he commands his infantry brigades, but as a Brigadier commands his battalions. It is as if an officer could properly command artillery when he had at the same time other more important things to think of; it is as if a brigade commander on taking over the command of the division were not to relinquish the command of his brigade.

V.

Besides the artillery brigades of divisions there would be only the artillery attached to cavalry. Cavalry without artillery must give way to cavalry with artillery, as was proved at Beaugençy, five days before Sédan. On the

other hand, cavalry away from an army ought not to fight without a special object in view. It would seem that one battery to a division of four regiments is the proper proportion of guns to cavalry.

If it be intended to make a great reconnaissance in force, after the manner of what was done by the Germans on the 15th and 16th of August to cut the line of the French retreat from Metz, horse artillery should be taken from the nearest division or divisions and lent to the cavalry. Batteries so taken should not delay to return into line. Batteries permanently attached to cavalry divisions should, as a rule, not be brought into line; they should be left intact.

VI.

In regular order of march, two batteries should march with the advanced guard of the division, two batteries should march in rear of the first battalion of the main body, and the remainder of the artillery between the two infantry brigades. The place of the artillery brigade commander would be at the head of the artillery of the main body.

Whenever it is practicable and safe, the artillery of the main body, preceded by a troop or a squadron, should march by themselves, on a line sufficiently parallel to or convergent with the line of advance of the infantry. Under certain circumstances, all the artillery, preceded by cavalry, may go before the infantry, as the artillery of the 5th and 11th German Corps passed on to go into action at Sédan.

VII.

If the old idea, still prevalent in our service, of making the artillery conform with the movements of the infantry, could be forgotten, and if artillery officers were to accustom themselves to think of a brigade of many batteries, it would not be too difficult for an artillery brigade commander to command his brigade in battle. The main guiding principles are these:—That artillery begin a battle; that all the artillery should be placed in action as soon as possible; that artillery should be massed; that artillery advances and changes of position should generally be covered by horse artillery; and that although artillery, and especially artillery massed, must generally be reduced to fire over their own infantry, the best support for infantry is artillery fire across their front.

A great battle is the attack and the defence of a position. On coming into contact with the enemy in position, the commander of the division and the artillery brigade commander should find themselves with the advanced guard. It might sometimes be considered advisable to wait for more troops to come into line; but in nearly all cases the advanced guard would attack at once. The two leading batteries of the main body should pass as quickly as possible to the front. The remaining batteries of the division would follow the main body of the leading infantry brigade, or pass more rapidly to the front, as should be ordered. There would always be the three battalions and the cavalry of the advanced guard to protect the four batteries first brought into action: whether the remainder of the artillery should first be brought up, or more infantry, would depend upon circumstances at the time. The

artillery brigade commander would place his batteries in action as they came to the front. His place in battle would be with the mass of his batteries. He would act, like the commander of an infantry brigade engaged with the enemy, on the orders of the Division General, or on his own responsibility. The point of attack and the plan of attack being determined by the Division General, and given in orders to the brigade commanders, the artillery should fight their way on, from position to position, under the orders of the artillery brigade commander, or the orders of the commanders of the leading artillery formations, unless the Division General found it necessary to give orders. An artillery manœuvred only by order of the Division General would be impeded in its action, as would be an infantry brigade which, when engaged with the enemy, was obliged to wait for division orders.

In defending a position, much would be ordered beforehand. The rule for artillery is to cross their fires from the flanks; but the rigid observance of this rule would sacrifice artillery of the defence to the more highly concentrated artillery of the attack. In defence, as in attack, artillery must be massed.

Division commanders and artillery brigade commanders should never neglect to take advantage of a favourable opportunity of massing their batteries on the batteries of other divisions. In the great artillery position between the wood of Vionville and Flavigny, the Germans had more than twenty batteries in line; and in the line of the Prussian Guard and Hessian artillery before St. Privat there were eighteen batteries. The German officers had so deeply studied war that they succeeded in spite of a faulty system: where many officers gave orders there was but one opinion.

VIII.

Our annual manœuvres are not manœuvres for artillery. Our manœuvres incline towards deploying the whole of the infantry on a very extended front, and manœuvring a scanty artillery by batteries. The lesson of massing artillery is not learned, because there are no batteries to mass. No true artillery tactics are learned.

If there were batteries to mass, if an artillery brigade of eight batteries were put into the field with each division, practice of true artillery tactics would be ensured, and our manœuvres could not fail to be more like war. That the battalions are not at their war strength is no reason for not giving the divisions their proper proportion of guns.

EXPERIMENTS TO DETERMINE THE COMPARATIVE LIABILITY OF COPPER, ORDINARY BRONZE ("GUN-METAL"), AND PHOSPHOR-BRONZE TO EMIT SPARKS WHEN SUBJECTED TO SHARP FRICTION OR PERCUSSION.

BY

MAJOR V. D. MAJENDIE, R.A.

H.M.'S INSPECTOR OF GUNPOWDER WORKS.

The experiments were carried out in one of the workshops of the Royal Gunpowder Factory, Waltham Abbey, after dark on the evening of the 26th October, 1874, in the presence of Colonel Younghusband, Major Majendie, Major Morgan, and others.

During each experiment the gas was extinguished, leaving the room in total darkness, so that the least spark could be readily distinguished.

The numerals distinguishing the different samples of phosphor-bronze experimented with, indicate different alloys, No. 2 being the softest and No. 8 the hardest.

The results are recorded exactly as they were noted down after each experiment.

The results obtained show that copper, gun-metal, and phosphor-bronze are all liable to emit sparks, or, as it is commonly called, "strike fire," when subjected to a certain description and degree of friction, the degree of liability appearing to vary with the different alloys and frictional surfaces, and, to some extent, with the construction and consequent rigidity of the article employed. So far as they went, these experiments appeared to indicate that the harder descriptions of phosphor-bronze emit sparks less readily than the softer samples, and less readily than ordinary bronze or even than copper.

The negative results obtained in series B and C can hardly be safely accepted as conclusively establishing the absolute non-liability of the various metals employed to "strike fire" under the conditions described. With a slight variation of those conditions it is not impossible that sparks would be obtained.

The real value of these experiments consists in the positive evidence

which they furnish as to the somewhat unexpected readiness with which, under certain conditions, sparks, and even a stream of sparks, more or less intense and continuous, may be obtained by friction from such metals as copper, gun-metal, and phosphor-bronze.

This result can hardly fail to possess a practical interest for manufacturers of gunpowder and other explosives, and for persons who are called upon to deal with and handle these substances.

At the same time, these experiments, as might have been anticipated, bear ample confirmatory testimony to the very great superiority of copper, gun-metal, and phosphor-bronze to iron or steel in regard to the liability to "strike fire."

HOME OFFICE, WHITEHALL,

1st December, 1874.

EXPERIMENTS.

SERIES A.—A "free grit" stone, of the same description as is used for sharpening small tools and razors, 6 ins. diameter, revolving 1220 revolutions per minute, and travelling 2079 ft. per minute, was supplied for these experiments, the material experimented with being in each case applied firmly to the revolving stone and held against it for about half a minute.

EXPERIMENT No. 1.—*No. 2 phosphor-bronze.* Occasional sparks and sometimes a stream.*

EXPERIMENT No. 2.—*No. 2 phosphor-bronze.* Sparks amounting to a small, feeble, continuous stream.

EXPERIMENT No. 3.—*Gun-metal knife* (thin). Gave a few sparks, but no continuous stream, and nothing like No. 2.

EXPERIMENT No. 4.—*Gun-metal lever* (stouter section and altogether harder than the knife). Numerous sparks and at times slight stream, but not quite so bad as 2.

EXPERIMENT No. 5.—*Gun-metal ingot,* for making bolts, &c. (Good casting). A few sparks, but chiefly a continuous feeble stream (only the cast surface applied, see 10).

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* I did not witness this experiment; Colonel Younghusband, who did, furnished me with the result.—V. D. M.

EXPERIMENT No. 6.—*Gun-metal ingot*, for making bolts, &c. ("Rotten" casting). A considerable uninterrupted stream of sparks, quite as bad as No. 2.

EXPERIMENT No. 7.—*No. 2 phospher-bronze* again. See 1 and 2. Got at first a feeble stream, but not so bad as No. 6.

EXPERIMENT No. 8.—*No. 7 repeated.* One or two faint sparks only.

EXPERIMENT No. 9.—*No. 6 repeated.* Got at once a continuous and lively stream of sparks. (The worst result up to this point).

EXPERIMENT No. 10.—*No. 5 repeated*, but applying only the strictly metallic surface. A strong stream of sparks, occasionally interrupted, but generally continuous. About as bad as 9.

EXPERIMENT No. 11.—*No. 4 phosphor-bronze.* Some very strong sparks, and at times almost a succession, but generally rather of the nature of a prolonged spark.

EXPERIMENT No. 12.—*No. 7 phosphor-bronze.* One or two strong sparks, but no indication of a continuous stream, less than No. 11. (N.B.—This is the alloy usually employed for the tools and fittings of gunpowder works where phosphor-bronze is used).

EXPERIMENT No. 13.—*No. 8 phosphor-bronze* (so hard that it can be used to chisel hard beech). Only one faint spark.

EXPERIMENT No. 14.—*Gun-metal ingot*, same as employed in 10. A considerable succession of sparks, but not quite so bad as No. 10.

EXPERIMENT No. 15.—*Copper sheet* (about $\frac{1}{8}$ in. thick), for press plates, &c. An intermittent stream of small sparks.

EXPERIMENT No. 16.—*Gun-metal casting*, for edge of press plate. 3 sparks.

EXPERIMENT No. 17.—*Iron rod* (wrought-iron). A bright continuous stream of fire; the sparks flew 6 ins. or more in some cases. Very bright and intense.

EXPERIMENT No. 18.—*Hardened steel* (file). Brilliant coruscations.

SERIES B.—A cast-iron cylinder 6 ins. in diameter, and revolving at 1220 revolutions a minute, was substituted for the "free grit" stone.

EXPERIMENT No. 1.—*No. 2 phosphor-bronze.* No sparks.

EXPERIMENT No. 2.—*No. 7 phosphor-bronze.* No sparks.

EXPERIMENT No. 3.—*No. 8 phosphor-bronze.* No sparks.

EXPERIMENT No. 4.—*Gun-metal ingot.* No sparks.

EXPERIMENT No. 5.—*Copper sheet*, $\frac{1}{8}$ in. thick. No sparks.

EXPERIMENT No. 6.—*Wrought-iron rod.* A brilliant stream of fire.

EXPERIMENT No. 7.—*Hardened steel.* Brilliant and rapid flow of sparks.

SERIES C.—A gun-metal cylinder 8 ins. in diameter, and revolving at 1625 revolutions per minute, was substituted for the iron cylinder.

EXPERIMENT No. 1.—*No. 2 phosphor-bronze.* No sparks.

EXPERIMENT No. 2.—*No. 7 phosphor-bronze.* No sparks.

EXPERIMENT No. 3.—*No. 8 phosphor-bronze.* No sparks.

EXPERIMENT No. 4.—*Gun-metal ingot.* No sparks.

EXPERIMENT No. 5.—*Copper sheet.* No sparks.

EXPERIMENT No. 6.—*Wrought-iron.* No sparks.

EXPERIMENT No. 7.—*Steel.* No sparks.

ERRATA.

Page 48, line 14, *for* "a rampart," *read* "ramparts."

" 49, line 15, *for* "owing to the nature of the ground and the disposition of the siege works, not be tied down," *substitute* "not be tied down by the nature of the ground and the disposition of the siege works."

" 52, last paragraph of part 2, *for* "little," *read* "no."

" 55, line 4, *for* "trajectory pencil," *read* "set of trajectories."

" 56, part 5, first paragraph (*not* the heading), *omit* "curved."

" 57, part 6, line 7, after "are," *insert* "therefore," and after "when," *insert* "necessary, as when."

" 58, lines 10 and 11 from foot, *for* "trajectory pencil," *read* "set of trajectories."

" 59, line 3, same correction as the last, and *for* "deepest," *read* "lowest."

" 59, line 25, *after* "lateral," *insert* "and longitudinal."

" 60, line 19, *for* "angles," *read* "angle," and *for* "are," *read* "is."

" 61, line 7, *for* "may," in second place, *read* "would."

" 64, last line, *for* "for," *read* "by."

" 69, line 12 from foot, *for* "rebound," *read* "glance."

" 73, line 27, *omit* "resulting."

" 74, line 11, *for* "circumstances," *read* "conditions."

MANUFACTURE OF PALLISER PROJECTILES, COMMON SHELL, AND SHRAPNEL SHELL FOR THE 9-PR. R.M.L. GUN.

BY

MAJOR W. R. BARLOW, R.A.,

CAPTAIN INSTRUCTOR ROYAL LABORATORY.

PALLISER PROJECTILES.

These projectiles are specially intended for the penetration of wrought-iron plates, which offer a great resistance to the passage of the shot; the plates being very tough and tenacious, but not very hard, as if made hard they would lose the tenacity which is absolutely necessary for the work for which they are intended. In order that the greatest penetration should be obtained from the projectile, it is necessary that its construction should be strong, its head of the form best suited to penetration, and the metal hard and unyielding. It is essential that the shot should not set up, or bulge, and that none of the work should be wasted in heating the shot. If tenacity could be combined with these qualities, a perfect projectile might be manufactured; but, so far, this has not been attained.

Looking to the question of strength alone, a solid shot would naturally suggest itself; but to this form there are several objections. The length is hardly sufficient to give good shooting, and the manufacturing difficulties are still more serious. Shot cast solid, of the metal for Palliser projectiles, have been found to be liable to fracture when lying in store, or to break up in the gun.* The 7-in. is the only calibre which has a solid shot, and this projectile is not found to be reliable; in fact, it is only re-issued from the Royal Laboratory for practice. It is therefore found advisable to adopt the form of a shell, or hollow shot. It is necessary to make the head solid, the walls thick, and the base as light as possible; in fact, to get the weight well forward. It is plain that a heavy base would be objectionable, as on impact it would have a tendency to break the walls;

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* Finspong projectiles are cast solid, but they are made of the best charcoal iron, and the base is quite soft, so that they can be cast with a dead head which is subsequently cut off.

thus we find that the base is made of about the same thickness as the walls, instead of being made thicker, as in common shell. The shot now, in all essential points, resembles the shell; it is, in fact, a small-capacity shell, and may be used as one—indeed it is plain that the difference is trifling, as the 11-in. shell was sealed as a shot, and then converted into a shell by the stroke of a pen. The shot now only differ in having a smaller cavity, the part towards the head being more solid. This entails a corresponding reduction in length.

The heads of all Palliser projectiles are ogival, and are now struck with a radius of $1\frac{1}{2}$ calibres; the radius of $1\frac{1}{4}$—which was formerly used with the 7-in., 8-in., and 9-in.—having been abandoned.

The change of form of shot from the small-cored shot of early construction was determined on after an experiment which showed that the large-cored shot penetrated as well at oblique angles as the older form. They were fired against plates at an angle of 60°, in comparison with the older form. The result was satisfactory; and as not only were there manufacturing advantages, but also as the shot thus made could be used as shell, the change has been carried out. With the old form fissures were frequently formed in the shot, and caused much loss in manufacture.

In addition to the projectile being made solid towards the head, it is necessary to adopt the form which is found most suitable for penetration. This has been found to be the same as that which answers best for overcoming the resistance of the air—*i.e.*, the ogival.

Various shapes were tried—flat-headed, hemispherical, and other forms. Valuable information on this subject will be found in Capt. W. H. Noble's report on the penetration of armour plates. The flat or punch-headed form was found inferior, especially for penetrating plates with wood backing; as it carried the piece of armour punched out in front of it, and this caused extra resistance in getting through the wood backing. The hemispherical-headed shot shared this defect. The blunt-headed shot were apt to set up; this also, perhaps, hindering the penetration. On the other hand, the ogival-headed shot did not set up, and in passing through the plate did not punch out a piece of metal, but bent it back. Hence the greater power of this form of head. Even after passing through many inches of iron there is no alteration of form; the point is found to be as sharp as it was before firing. A table in Captain Noble's book (p. 17), shows the superiority of the ogival head over the hemispherical. A Belgian conical head also gave good results.

The success of the Palliser projectiles mainly depends on the metal employed and the care taken in casting. Many experiments were carried out under Colonel Boxer and Mr. Davidson, Manager Royal Laboratory, before the proper metal was arrived at. A great reduction in cost has been effected by the employment of cheaper iron, by Colonel Milward, C.B. The metal must be hard, and of a peculiar nature of iron, otherwise it would not chill properly. It is selected of such a nature that when cast in sand, as in the body of the projectile, it is mottled. It would not do to employ white iron, though it is intensely hard, and so far suitable, as the shot made from it would be far too brittle.

To understand the importance of using a hard, rigid material, and not a soft, yielding one, it must be remembered that, independent of the fact that a change of form might, perhaps, cause more mechanical resistance to the

passage of the shot through the plate* and wood backing, any amount of motion set up in the particles of the projectile itself is so much force wasted. If soft iron shot are fired at iron plates they become intensely heated, while the chilled projectile remains cool. If the shot could be picked up immediately after impact, and the amount of heat produced by the effect of the blow accurately measured, there would be no difficulty in calculating the exact amount of force lost by conversion into heat. The mechanical equivalent of heat is as follows:—The quantity of heat that would raise 1 lb. of water through 1° Fah. is equivalent to 772 foot pounds. Sir W. Armstrong made some experiments which probably afford good approximate indications of the amount of force expended in heating shot of different degrees of hardness. With hard and well-tempered steel shot, the work expended on the projectile was about $\frac{1}{10}^{th}$ of the total amount of work in the shot on impact. 2. With soft steel, about $\frac{2}{10}^{ths}$ of work. 3. With soft wrought-iron, about $\frac{1}{2}$. Cast-iron eluded observation, as the shot broke up into fragments which could not be collected.

It would therefore be undesirable to sacrifice hardness in order to get a more tenacious material.

Independent of the mode of casting, the manner in which the carbon present is associated with the iron depends on the nature of the ore from which the iron is smelted. In hard white iron the carbon is chemically combined with, and alters the qualities of, the iron; in fact, it is no longer iron, but a carbide of iron, not possessing the tenacity of iron, but on the other hand gaining the qualities of intense hardness and great strength to resist crushing—exactly what is required in the ogival head of a Palliser projectile.

Several causes are known to be favourable to the chemical combination of the carbon—such as the presence in the ore of manganese, or sulphur. The former action is said to be due to the fact that the carbide of manganese resists the high temperature which appears to break up the chemical combination of carbon and iron; the cause of the action of sulphur I have not seen stated, but it is known that white iron is produced from ore containing pyrites.

White irons are rather cheaper than the dark varieties, as they are produced by using less fuel in the blast furnace, for the reason given above, that a high temperature breaks up the combination of carbon and iron.

In the Royal Laboratory, iron of the required degree of hardness is obtained by mixing white iron and grey, or by using mottled irons to start with; but the former method is the usual one. Store scrap—*i.e.*, old shell re-melted and run into pigs—has also been employed in the proportion of from 20 to 25 per cent. The smaller shells will bear a larger amount of store scrap than the large ones, because the effect of the chill is greater on the smaller body, thus allowing more soft iron to be used.

A very important part of the manufacture of Palliser projectiles is selecting the iron. Nominally, pig-iron is sent in by the manufacturer of a certain brand or number; but though this gives a general idea of the character of the iron, still there may be a good deal of variation in the degree of hardness.

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* The hole torn through the plate by the front part of the shot is most likely large enough to allow for any alteration in form.

This is probably unavoidable, as the iron from a blast-furnace may vary much, even though the ore smelted may be the same. All depends on the working of the furnace, blast, &c., which is liable to variation. Hence all iron is broken up and carefully sorted, the look of the fracture enabling an experienced man to tell the hardness of the iron. Store scrap is similarly selected after being run into ingots.

Different mixtures of Ridsdale and Cwmbran irons (either white or high numbers of pigs) have been used in combination with about 20 per cent. of store scrap.

It has become very desirable lately, on the score of economy, to use up the large existing store of S.B. guns and projectiles. The price of the iron has by this means been reduced to about half, while a recent trial at Shoeburyness against armour plates shows that the projectiles compare favourably with those made up with the more expensive mixture.

Many experiments were carried out in the Royal Laboratory, and considerable difficulties were experienced, as it was found difficult to get a mixture containing much old gun and shell iron to chill properly.

The addition of ilmenite*—an ore of iron in combination with titanic acid—was found to bring the mixture of iron to a state favourable for the process of chilling, and since October, 1874, shells have been cast of iron consisting chiefly of old gun and shell iron;† something under 10 per cent. of Ridsdale white iron, and about 5 per cent. of ilmenite are added.

The process of chill casting has been well known for a long time, but to Major Palliser is due the credit of the application of this method to projectiles, thereby effecting a very large saving by substituting Palliser projectiles for steel—which are very costly, and unless great care was taken in the manufacture, apt to be uncertain.

The process consists in casting the metal in iron moulds, the whole process turning on the conducting power of the metal, which causes the casting to cool rapidly, and thus favours the carbon remaining in chemical combination with the iron. Rapid cooling is always unfavourable to the formation of large crystals, and there seems to be something analagous in its not allowing the carbon to crystallise out into the graphitic form which it assumes when the metal is slowly cooled. The result on the metal is to make it intensely hard, dense, and brittle, of great strength to resist crushing, and showing a brilliant white fracture. Two points are necessary to attend to—to heat the chill before beginning to cast, and not to pour in the metal too hot. The first prevents the metal being defective where it comes in contact with the chill. If it is quite cold there are apt to be flaws, &c.—in fact, the suddenly cooled iron will form "shots;" also, the chilling is found not to penetrate so deep. If the second precaution is not taken, the hot metal injures the chill, and as

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* Ilmenite has been analysed by the Chemist, War Office, with the following result:—

Iron oxide, equivalent to 45·3 metallic iron	61·4
Titanic acid	33·2
Silica	4·2
Tin oxide	1·2
Manganese	Trace.

† The guns are nearly cut through in a lathe to convenient lengths, and then broken up under a steam hammer.

these are costly to manufacture, care has to be taken to avoid it; but the metal should be as hot as it possibly can be without injury to the chill.

There are some peculiarities about molten hard iron. The break, when a rod is drawn over its surface, is peculiar—forming long lines or ridges, very different to the star-like break of soft iron. It throws off more sparks; but a more important peculiarity, which affects manufacture, is that it is not so fluid as the soft iron, and it soon passes into a pasty viscous condition, and contracts nearly double as much as soft iron in cooling. It melts at a lower temperature than grey or soft iron.

The chills in which the heads of the projectiles are cast are turned from cast-iron to the required ogival shape, the head being struck with a radius of 1½ diameters. They form a lining to larger blocks of cast-iron, so as to avoid the expense of re-casting a large mass of metal when a chill wears out. (A chill for a 10-in. will last about 70 castings; the lining costs about 50s.)

The chill warps and sometimes becomes flawed after it has been in use, and if the iron is put in too hot a new chill may be spoiled at once. Holes are made through the chill to receive two steel rods, which form the extractor holes. With all natures, except the 11-in. and 12-in. 35-ton, holes are made in the chills to receive the loam cores which form the recesses for the buttons; small holes, leading to a groove cut in the large block, form gas escapes for the gas from the buttons.

Chills add to the expense of casting. As the final shape is given by them to the head, they have to be replaced when only slightly damaged.

Before use, the chills are cleaned out with water, and are smeared with tallow and China-clay, which fills up any cracks in the chill. The chills are made larger than the head, to allow for the shrinking of the projectile in cooling.

As Palliser projectiles are cast as near as possible to their final dimensions, greater care is taken in incorporating the sand and coal-dust used for moulding than when casting other shells. It is passed under revolving cast-iron runners, which thoroughly mix up the ingredients.

The mould contains the body and base of the shell. It is formed by placing two cast-iron moulding-boxes (which are keyed together, fastening on to one another with a recessed joint, and pierced with holes to allow the gas from the heated coal-dust to escape), over a "pattern" of the shell.

The "pattern" resembles the shell, but is a very little larger in diameter, so that the casting is slightly larger than the finished projectile. It is so arranged as to easily run up or down through the moulding table, and is fitted with studs which can be turned in and out, and which form recesses in the mould into which loam cores can be fitted. From the top of the pattern a cylindrical rod projects, which forms a hole in the mould through which the spindle of the core passes.

The pattern being run up and its studs turned out, the moulding-boxes being over them, sand and coal-dust are rammed in carefully with iron rods until the moulding-box is filled; holes being made to form the "runner" and "riser" by inserting two sticks which touch the base of the pattern. These holes allow the metal to flow in and rise when the shell is cast. The depth of the upper box is almost entirely taken up by these holes; so the metal, when poured in, rising in these holes, forms a kind of dead head to the shell. When the ramming of the sand is finished, the buttons of the pattern are turned in, the pattern lowered, and the mould removed.

The core is formed on a hollow spindle, pierced with holes to allow the escape of gas. The core-box, in which it is formed, is divided vertically into two parts, which can be drawn asunder. The spindle has a cast-iron ring having vertical grooves, and also horizontal steps running round its exterior circumference, in order to unite it firmly with the metal of the shell fixed to its base. This ring replaced the tinned wrought-iron ring used up to November 1874. The cast-iron is found to adhere better to the metal and to resist blows given by a steam hammer better than the wrought-iron. By its introduction a saving of about £5 a hundred will be made. To support the core, wooden pegs are passed through the holes in the spindle. At the exterior of the cast-iron ring at the base of the spindle a clay ring is placed, which forms an undercut recess between the cast-iron ring and the base of the shell. (Into this recess a lead ring is finally pressed, just before the shell is finished, so as to seal the junction). The spindle is placed in the box with the ring down, and the sand, &c., rammed in. The sharp point of the core is secured by placing long iron nails so as to hold it together. When the core is finished, the box is drawn apart and the core removed. Both core and mould are smeared with beer dregs, to give a hard, smooth surface. All cores and the moulds for projectiles of and over 10 ins. are dried in a hot room. The coal-dust in mould and core prevents the sand from adhering firmly to the iron, and causes it to break up easily.

When the mould is ready, loam cores, so shaped as to form undercut recesses in the shell, are placed in the holes in the mould, and the core is put in, carefully adjusted, gauged, and keyed up; the box is then secured to the chill, and is now ready for casting.

The metal is melted in a cupola furnace driven with a cold blast. About 10 cwt. of iron, $1\frac{1}{2}$ cwt. of coke, and $\frac{1}{2}$ cwt. of chalk form a charge.*

The molten metal is tapped, and flows into large iron ladles lined with fire-clay. It is allowed to stand for ten minutes or so after tapping. This time will vary with the heat of the metal, which depends on the blast and other causes. Small ingots are cast each time the furnace is tapped, to allow the foreman to judge if the metal is correct. The ladles are wheeled to the casting-ring, any scum or slag that rises is skimmed off, the ladles are raised by a crane, and the molten metal poured into the runner till the metal flows up and appears in the riser. The hard iron is poured in till it rises about two inches above the bottom of the shell, and then the runner and riser are filled up with very hot soft iron. This is done to make up for the shrinkage of the hard iron, and to ensure the base of the projectile being the last part to become solid. It has been pointed out that hard iron in cooling rapidly passes into the viscous condition; hence the necessity for using a metal which remains longer fluid, and in a condition favourable for flowing into the shell. If this was not done the base of the shell would be full of flaws, and the shell would be below its proper weight. Prior to November, 1874, no soft iron was added, but the metal in the riser was constantly stirred up and down with an iron rod (in large natures sometimes stirred both at runner and riser).

The shells remain in the moulds till they are sufficiently set not to be injured by removing. A 9-in. shell may remain about $\frac{3}{4}$ hour. When

* The use of chalk is explained in the "Manufacture of Common Shell."

NOTE TO FACE PAGE 128 (NO. 3, VOL. IX.)

Line 12 from bottom. Add after the words "very hot soft iron":—This method was uncertain; shell so cast were apt to be insufficiently chilled, therefore at present no soft iron is added. An iron box, lined with fire-clay, containing two small holes through which the metal flows, is placed over the mould. The metal is poured in till the shell is filled and rises a little in the "runner and riser"—which are made large; the box is then removed, and the "runner and riser" filled with very hot hard iron. The large mass of metal keeps sufficiently hot to allow the shell to "feed."

taken out, the head is cooled by the chill to a dark colour, while the body is still red. The upper box is removed, the spindle withdrawn, and the runner and riser cut off the shell with a broad chisel; the shell is removed from the lower box, and wheeled off to a pit partly filled with dry sand, where it is covered over for 14 or 18 hours.*

The object of casting the head down is to obtain as sound a head as possible.

The foreman is enabled to judge how the work is turning out by inspecting the fracture of any defective castings, which are broken up under a steam hammer; the weight of the projectile is also an indication of the quality of the iron, as the shell would run light if a soft or not dense enough metal was employed.

The difference between the metal body cast in sand and the head is very marked in a fractured shell; the body having a well-defined mottle, while the head is a bright white. The effect of the chill extends some way into the body. It is important to remark that the head is not touched by any tool after leaving the chill; if the skin was removed, the strength of the head would be reduced. It is a well-known fact that the strength of a casting is materially reduced by turning off the outer skin, which is always the soundest and densest part of the casting, the quick cooling preventing the formation of large crystals.

When the shell are sufficiently cool the core is scraped out, and while still hot the shell is lacquered. It is not desirable to heat these shell by steam, like common shell, as they may be injured by change of temperature. They are next tested by water pressure, 100 lbs. to the square inch, and the bases are carefully hammered all over with sharp-pointed hammers to detect flaws. The body is then ground down to the final dimensions on a revolving grindstone, as the metal is too hard to be turned in the ordinary way. The shell is placed in a lathe, and the cast-iron ring in the base tapped to receive the plug. The studs are pressed in, turned and planed, the lead ring sealing the junction of the cast-iron bush and the body is hammered in, the studs trimmed by hand, and the base-plug—which is not interchangeable—carefully fitted to each shell. The plugs are smeared with equal parts of cocoanut oil and ground chalk. The plugs are made long to fill up the recess, to avoid any risk when the powder sets back.

Finally, the shell are gauged and examined. The limits over the body are ± ·015 in. instead of ± ·01 in., as in common shell. The following gauges are used:—High and low ring, over body, do. over studs, cylinder gauge.

On the base of the projectile will be found "Palliser shot,"—or "shell," as the case may be—also the calibre of the gun, and if 12-in. the weight of the gun will also be given. The month and day of casting will also be found on the base, and also two letters indicating the iron used in casting, if cast prior to November 1874. The month and year will be found on one of the studs; also a ×, to show that the studs are planed to fit the grooves. The *E*, which indicated that the projectile had been examined, was discontinued in 1873. All shells of that and later date may be considered as having been examined and tested as above.

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* This is important, as it is essential that the shell should cool slowly, otherwise it will be brittle.

COMMON SHELL.

Iron used for Shells.

The quality of the iron mainly depends on the quantity and condition of the carbon associated with it. The various impurities—such as sulphur, silicon, phosphorus, &c.—which are generally found in pig-iron, are more or less injurious. Sulphur is thought to diminish its strength, but is sure to be present, as the fuel—coke—is not free from it; phosphorus may not be so injurious, and is said to increase its hardness and fusibility; while silicon is said to diminish its strength. The three classes of iron—cast-iron, wrought-iron, and steel—run into one another so that it is hardly possible to lay down a fixed line.

Cast-iron contains generally from about 5 to 2 per cent. of carbon. ("Spiegle eisen" contains as much as 4 per cent. chemically combined carbon.) It would seldom be found to have over 3·7 per cent. Steel would contain from about 1·4 to ·25 per cent., and wrought-iron from ·25 to a trace.

Tensile strength per square inch:—Cast-iron, from 5 tons to 14 tons; wrought-iron, along the fibre, 22 tons; steel, cast, 40 tons; Bessemer steel, from 40 to 64 tons.

Crushing strength:—Cast-iron, from 22 tons to 58 tons.

All the above figures must be taken only as approximations.

Pig-iron is used in the manufacture of shells. It is sometimes classed by numbers from 1 to 8, 1 being the softest.* (The price of No. 1 is rather higher than the others.) The same ore will produce different varieties of pig, according to the working of the furnace. The white is produced by diminishing the proportion of fuel employed in smelting the ore. (It is said that the high temperature causes the chemically combined carbon to separate from the iron, and on cooling it assumes the form of graphite.) The nature of the ore has also some influence on the condition† of the carbon. Thus, if manganese is present, white iron is more likely to be formed;‡ as the carbide of manganese resists the action of the high temperature, and when dissolved in the iron probably produces the same effects as the carbide of iron. The quality of the iron does not simply depend on the amount of carbon present, but on the manner in which it is combined. Thus, if it exists in the form of graphite, the iron will be grey in appearance, and will have more of the qualities of pure iron—*i.e.*, would be soft and tenacious—while, if the carbon is chemically combined, the iron becomes very white, hard, and brittle; it is also more dense. Lying between these extremes is mottled iron; so

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* "Construction of Artillery," Mallet, p. 231. No. 1 pig, soft, very dark grey in colour, very fusible, containing a very large portion of uncombined carbon in the shape of graphite, diffused in scaly or micaceous crystals through the mass, upon which it confers its peculiar form of large, pretty uniform, but irregular and ill-developed crystallisation, with its dark grey metallic lustre relieved here and there by light reflected from the flat faces of spangle-like crystals, some of which can often be separated and thrown away from the surface. This pig is the most fusible and liquid when melted, the least rigid and tenacious, and the softest when cold.

† Sulphur is said to favour the production of white iron.

‡ Pyrites in blast-furnace has long been known to produce white iron. Mallet's "Construction of Artillery," p. 226.

called because specks of graphite mottle the surface of the white iron. There is a great difference in the appearance of pig-iron made at different works; even the pig-iron from the same firm may vary much, though the number of pig may be the same. Any variation in the blast, fuel, &c., in the furnace will tell on the iron,* and even out of the same running there may be a difference in the pigs. In all cases the "sow" will be found to differ in appearance from the pigs which she feeds. Being larger, the metal cools more gradually, favouring both the formation of large crystals and the separation of graphite. For the manufacture of shells, it is desirable to have a dense, close-grained iron; not too hard to turn, as it would then injure the tools and largely increase the cost of manufacture, as the rate of driving the turning-lathes would have to be lowered. It will be seen in the manufacture that a cut of nearly ·1 in. is taken from the exterior of the shell. It is necessary to go to that depth, as the exterior of the shell is very hard, and would injure the tools. It is probable that turning takes off more than would be imagined from the strength of the casting. It is known by experiment that a cast-iron girder not planed down is stronger than one which is reduced to the same dimensions by means of planing. In fact, taking off the outer skin must, to some extent, diminish the strength of a casting, as the soundest and most dense part of the iron is removed.† If a broken shell of some considerable thickness is examined, the fracture will clearly exhibit the closer structure of the exterior of the shell, and also of the interior. The walls cooling first on the outer and inner surfaces, the central part is liquid while the walls are set, and the contraction on cooling causes the central part to be more open in the grain, as it cannot receive any fresh iron to make up for the contraction; the walls, on the other hand, can feed themselves at the expense of the still liquid centre. Hence the difficulty of getting a very thick casting sound. This also shows how thickening a part of a casting, especially if there is a sudden alteration in form, may actually weaken instead of strengthen a shell. Instances may now and then occur where the thick bottom of a common shell is quite spongy, owing to the quicker cooling surfaces feeding themselves at the expense of the base of the shell.

We cannot trust to the numbers of the pigs to choose the fit iron for shells. The pigs are broken up and selected, the viewer being able to tell by experience what kind to take as suitable for the shell, and what to put on one side for re-melting in company with other iron so as to bring it to the required standard. Scrap iron—*i.e.*, iron produced from breaking up old shells—is also melted up and run into pigs for the purpose of selection, and then mixed in the proper proportion for the shells required.‡ Re-melting is found to harden iron. This seems to confirm the idea that a very high temperature may produce soft iron, as the temperature in the re-heating furnaces is not generally so high as in the smelting furnaces.

The metal is melted in cupola furnaces, of which there are eight in the

* The position of the tuyeres also affects the iron.

† Some trials have been made of casting shells to their final dimensions, and the result was good. Some expense would be caused by the greater accuracy necessary in moulding. The whole question is a large one, and much consideration has been and still is given to it in the Department.

‡ Shells made of iron of known quality are not run into pigs, but are placed at once in the shell furnaces.

Department. Each cupola is capable of running about ten tons in an hour, but the quantity will vary with the rate of driving. There are two rows of tuyeres. The upper one is generally not used; if, however, it is desired to increase the yield, the upper row may be used. The cupolas are blown out, and undergo minor repairs daily. They were formerly lined with fire-brick, but now ganister is employed, by which a considerable saving is effected.* The furnaces require re-lining about once a fortnight.

In August, 1874, a charge for the cupola consisted of:—

Gun iron	30
Old shell	60
No. 1 Ridsdale or Cwmbran	10
	100

About 1½ cwt. of coke is used to 10 cwt. of iron, and ½ cwt. of chalk is added. The use of the chalk is to combine with the silica always present in pig-iron (the pigs being cast in sand moulds). If the chalk was not added, the silica would combine with the iron and cause a loss. Lime, also, gives a fluid slag which disengages readily from the iron, thus preventing its entry into the castings. If too much lime is used the lining of the furnace is rapidly eaten away; the sand of the lining combining with the lime. A thick strong slag sometimes causes "scaffolding;" the slag forming a network which, for a time, supports the superincumbent charge, but which finally gives way, and the fall of the heavy mass into the molten metal may cause an accident.

The charges of iron above given must be taken as approximate only, as they are liable to vary from day to day according to the quality of the old shells, guns, and pig-iron employed. The foreman in charge states that even the weather has an effect on the nature of the metal produced by the furnaces. The object in view is to produce a sound, close iron, not too hard to turn. The furnaces are tapped about every ten minutes (when ladles containing about 6 cwt. are used), and the slag is run off about every three hours. The heat of the furnace depends on the rate of driving, &c. It is necessary to have the iron very hot to produce sound castings.

The metal is run into iron ladles lined with loam, containing about 6 cwt., from which smaller ladles containing about 1½ cwt. are filled, and thence the metal is poured into the moulds; care being taken to pour with sufficient rapidity to keep the runners filled, so that any cinders may remain on top, and not be carried down into the shell.† Gas is formed from the coal-dust in the moulds and core, and burns out through the perforations of the mould and at the neck of the hollow spindle. The shells are allowed to remain about an hour in the moulds. For large shells—8-in. and upwards—cranes are necessary for lifting. A convenient form for casting is to have a ring with a revolving crane in the centre.

Moulds and Cores.

The material employed is sand and coal-dust, brought to the desired consistency by mixing "green sand"—that is, sand which has not been pre-

* Ganister is the name given to a species of silicious stone.

† A small strainer made of clay is placed in top of the runner of larger shells.

viously used—with "burnt sand"—*i.e.*, sand which has been used for casting—in about equal proportions (about $\frac{1}{8}^{th}$ coal-dust being added for moulds), mixed by passing through a revolving sieve. For making cores, a larger proportion of burnt sand is employed, to make the core break up easily. Coal-dust is added to all moulds and cores. Where any tool work is required it is necessary to use coal-dust, as it prevents the sand adhering to the sides of the shells, which would injure the tools employed for turning them. It is useful in the cores, as it prevents the core from adhering to the sides of the shell, and makes it break up better. Beer dregs are used to paint over the moulds and cores. They give a smooth surface, and render the mould or core less liable to chip. All cores are dried, after they are made, in the hot rooms, and all moulds from 10-in. and upwards.

The cores are formed in cast-iron boxes, which represent the interior of the shell, but have an allowance made for the shrinking of the metal. They are formed on perforated iron spindles; and for all except small shell the core is supported by small pegs of wood.* Some spun yarn is wrapped round the spindle. Both sticks and yarn are charred by the heat, and allow the core to break up readily and separate from the spindle. A projection round the neck of the core makes a groove in the neck of the shell, which facilitates breaking it off, on trimming the shell. The spindle fits into a cast-iron neck, which is coned to fit into a conical recess in the top of the moulding-box (which is made in two parts), and slotted to receive a key, which keeps it in its place. The core-box is filled with the mixture of sand and coal-dust, and well pressed in. The top of the core is formed by placing a cup-shaped top or lid over the mouth of the core-box, working it round and giving it a few smart blows. With large cores a hook is inserted at the base, for convenience in hanging the core up. This is removed before placing the core in the mould, and the hole filled up.

The chief thing to remark in the construction of the moulding-box is the manner in which the rod carrying the core fits into the coned hole in top of the moulding-box. When the core is keyed up, its position is tested by a gauge, and great care must be taken that it is accurately placed, as the least error would render the shell eccentric, thus making the wall thin on one side. The limits allowed are very small, $\pm$ ·05 in.

The mould is divided into two parts horizontally, which are keyed together; the lower box forms the base,† the upper contains the rest of the shell, also the runners and curved opening leading from the runners into the shell. The object of having the runner arranged in this way is to prevent injury to the base of the mould, which would happen if the metal was allowed to flow directly into the shell. The curved passage gives the metal entering the mould a sweeping direction, which tends to throw any scoriæ, &c., to the outer part of the shell. The model on which the mould is formed is larger than the shell, to allow of its being turned down in subsequent manufacture. A rod projecting from the top of the model forms the hollow in which the core-spindle is inserted; and two projections on the model form ears on the shell,

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* Some large shells have the core supported by cast-iron rings with arms, nicked so as to break easily.

† On the mould which forms the base are the letters R.L. and the ⅄, the day and month of casting, and upon 7-in. and upwards the calibre of the shell.

which are used in subsequent turning processes. A few small holes are made into the mould, to allow of escape of gas when the metal is poured in through the runner. The shells are cast base down, as most strength is required there to resist the shock of the discharge. The lower part of a casting is always the soundest.

When the shell is sufficiently cool it is taken from the foundry (in a truck which hooks on to the trunnions of the casting-box), the mould is unkeyed and the shell knocked out, the runner is removed and core-spindle taken out. 9-in. and upwards are piled close together upon their base, and allowed to stand for about 12 hours; 8-in. and downwards have sand placed round them for about 12 hours.

The shell next goes to a shed where the core is thoroughly removed, and the sand is scraped from the exterior with a coke scraper. The nose of the shell is knocked off. The shell goes to the turning-room, and is centred. In one lathe it has its nose cut to proper length, and turned down to the proper curve; the fuze-hole is bored out to correct size, tapped to receive the gun-metal bush,* and has a recessed groove cut at the bottom. The bush is next screwed in, and violently jammed home to expand it into the recessed groove. It is tapped with a screw-thread—G.S. gauge—and its end is cut off, leaving a recess ·2 in. deep.† The extractor holes are bored, the body is turned, the stud-holes are bored out and undercut.

Steam Testing.

Steam is admitted into the shell at a pressure of 40 lbs. to the square inch. This detects any porous shell, and also serves to heat the shell to the required extent for lacquering.‡ The lacquer (Spanish brown, resin, plaster of Paris, and turpentine) is poured in hot,§ and immediately poured out again. The shell is thus given a fine uniform coat of lacquer.‖

The gun-metal studs,¶ which are softened by annealing, are then pressed in. They have a concave hollow in the lower part, which causes them to expand into the undercut hole. The pressure has been estimated by Captain Sladen as equivalent to a statical pressure of about 30 tons on a 7-in. shell.** After pressing in the studs they are turned, and planed in another machine to fit the rifling. A machine with a bar which can be set so as to give the required angle of rifling is employed. Finally, all the studs are filed and trimmed by hand, and afterwards weighed and gauged.

Limit of weight, ± 1½ per cent.

Gauging:—(1) thickness of sides, (2) thickness of base, limits ± ·05 in.,

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* Field service shells are not bushed with gun-metal.

† The 40-pr. is not recessed, the bush is flush with the top of shell.

‡ Up to 25-pr., inclusive, lacquering is done before tapping the fuze-hole, as the shell being small turnings can be seen and readily removed.

§ A funnel-shaped gun-metal bush is screwed into the fuze-hole, to prevent the lacquer filling up the threads. It is removed after the lacquer has set.

‖ This process used to be carried out before boring the fuze-hole. The iron trimmings were found to adhere to the lacquer of the shell, so it was advisable to lacquer after turning.

¶ Copper is used for some of the small shells.

** Experiment has since shewn that the calculation was a good approximation; the experiment gave about 27 tons pressure.

(3) screw-gauge fuze-hole, (4) plain plug to test pitch of fuze-hole, (5) recess-gauge fuze-hole, (6) high ring-gauge body, (7) low ring-gauge body, (8) high ring-gauge studs, (9) low ring-gauge studs, (10) cylinder gauge.

$$\text{Limits} \begin{cases} \text{Body} \ldots\ldots \pm \cdot 01 \text{ in.} \\ \text{Stud} \ldots\ldots \pm \cdot 005 \text{ in.} \end{cases}$$

Finally, the shell is stamped and painted. Upon the body of the shell are stamped the letters R.L. and the ⅄, also the numeral. These marks will be found above one of the front studs in all calibres above the 64-pr., inclusive; in 40-pr. and downwards, below one of the front studs. On a rear stud is stamped the month and year of manufacture, and upon 7-in. and upwards a ×, to indicate that the studs have been planed as well as turned.

SHRAPNEL SHELL FOR THE 9-PR. R.M.L. GUN.

THE exterior of the shell is made in two parts:—

1. The body.
2. The head.

The method of casting the body is similar in most respects to that given for common shell. The details of making the mould and core for body are the same, except that as the body consists of a cylinder open at top and closed only at bottom, the top of the core is so formed as to fit without leaving any space between it and the top of mould. At the bottom the core contracts, so as to form a powder-chamber; and has six projecting ribs which form grooves on the interior of the powder-chamber only.* The interior of the body is slightly conical, tapering off gradually from the powder-chamber to the top.

The shell undergoes the same processes of knocking out and trimming as the common shell, but is not lacquered. The shell is then centred from inside and the body rough-turned in a lathe. A recess is next turned down on the upper part of the exterior of the body, over which the head fits;† the body is then fine-turned. The operations for studding are next carried out in the same way as given for common shell.‡ The shell is gauged for thick-

* The ribs are continued along the body of the core in all other calibres, to facilitate opening the shell, tapering as they approach the top, except the 16-pr., in which the grooves are dispensed with altogether.

† The recess in the 7, 9, and 16-prs. is not so deep as formerly, as the rim of cast-iron was weakened and broke off. The rim has been thickened, the metal of the head being turned down to a corresponding amount at the junction.

‡ In all calibres—9-pr. excepted—care must be taken to keep the stud holes, as far as possible, clear of the lines of least resistance.

The shell is tapped with a hammer, to ascertain whether it has been cracked by the pressure applied in attaching the studs.

ness of metal and then weighed. The head is placed upon the body at this stage of manufacture, and two rows of rivet-holes are drilled through into the body of the shell—one row close to the rim of the shell body, the other further from the rim. The first, being nearly slotted through the metal, offer little resistance to the action of the powder in a longitudinal direction, but serve to resist the tendency of the head to separate, owing to the rotation of the shell. (These are sometimes called "twisting-holes," and the pins which fit into them "twisting-pins.") The second row resist the tendency of the head to separate, both longitudinally and laterally. The body is now complete.

The head is formed of either the best charcoal iron, or of a very mild steel which is produced by the Bessemer process. It is punched into discs, and is then stamped in dies, to bring it to the required ogival form. (It is stamped into the first die cold, and brought to its final dimensions by heating to a red heat and stamping into three dies; each die becoming more contracted, so as to bring the metal gradually to shape without unduly straining it.) The head is punched out and afterwards recessed to receive the collar of the socket for the fuze. It is turned on the interior of rim to fit on the body, and a very little turned off the exterior to give a clean surface for the solder. It is then placed on the body and the rivet-holes drilled; the shell and drills being so adjusted as to allow of two holes being drilled at a time. The head is afterwards removed. A wood lining of either ash or beech fits into and supports the head. It consists of a piece of wood of ogival form, to fit into the head.

The remaining parts which constitute the interior of the shell are—the tin cup, the diaphragm, the tube, the tin socket, the gun-metal bush, the mixed metal balls, the felt or kamptulicon disc, and brown paper lining. A brief description is subjoined:—

Tin Cup.—Of tinned iron, formed so as to fit the powder-chamber, covered on top except a small hole in the centre, where a short tube is soldered on to fit the hole in diaphragm.*

Diaphragm.—A wrought-iron disc, having a hole bored through its centre and tapped for the reception of the tube.†

Gun-metal Tube.—It is enlarged at the head where it is soldered to the tin socket, tapped on the exterior at bottom to enable it to be screwed into the diaphragm, and on the interior at top for the gun-metal primer.‡

Tin Socket.—Made of iron tinned, conical in form. The smallest end fits round the gun-metal tube, to which it is soldered.

Gun-metal Bush.—It is cast roughly to shape, and then turned in a lathe

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* The cup has a flat top for the 7 and 9-prs., and coned for all other calibres, to facilitate unloading.

† The bottom is flat for the 7 and 9-prs., and coned for all other calibres, to facilitate unloading.

‡ A wrought-iron tube, lacquered internally, tapped on exterior at bottom, and slightly recessed on the interior at top to receive the lower part of the gun-metal socket, is used for all calibres above the 25-pr. (the tube for the 40-pr. fits into the lower part of the metal socket).

to its final conical form, with a rim, and tapped with a screw on the inside to G.S. gauge; it is then soldered into the head. (The bush and head are heated for this operation; and after soldering it is washed in a ley of soda-ash and water, to remove superfluous acid.)* The firmness of the junction is tested by hammering the socket.

Bullets.—Are of mixed metal, 4 lead to 1 of antimony. There are 28 of 18 to the lb., and 35 of 34 to the lb.†

Felt or Kamptulicon Ring.—This is simply a ring of the material mentioned (soaked in kit composition for the 7, 9, and 16-prs.)

Assembling the Shell.

This operation consists in putting together all the component parts of the shell. The tin cup is dropped into the recess in the bottom of the shell, the diaphragm—with an iron tube temporarily screwed in—is next inserted (the tube keeping the place for the gun-metal tube and tin socket), brown paper is placed round the sides of the shell to keep the resin from adhering, the lead and antimony balls are inserted, the iron tube removed and the gun-metal one screwed in, the resin run in, and the felt or kamptulicon ring inserted; the wood lining of the head is placed over the washer. The head, having the gun-metal bush soldered in, is now put on.

The shell is now placed in a screw-press, and pressed together. It is essential that the wood head should be pressed firmly down on the felt disc. The rivets are placed in the twisting-holes, and the head riveted on to the body. The shell is taken out of the press, and the holes for the screws tapped, and the screws—four in number—placed in,‡ the heads of screws and rivets filed off flush with shell. The body and head are further connected by a ring of solder.§ The shell is placed in a lathe, and the solder evenly turned down. They are next trimmed, gauged, and painted. The gauging is the same as given for common shell, except that the thickness of shell is not gauged at this stage, and a gauge is applied to test the correctness of screw for primer in the tube; this gauge also ensures a proper length being left for fuze. The body of the shell is painted black, and the head red.||

Royal Laboratory,
February 1875.

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* A metal socket, contracting at the lower end to fit into the tube (except in the 40-pr., where it fits on the outside), and tapped on the inside for the primer, takes the place of the gun-metal bush and tin socket in all calibres above the 40-pr., inclusive.

† Mixed metal bullets, varying in size and number, are used for all B.L. shrapnel, and for M.L. shrapnel up to 80-pr., inclusive; sand shot are used for the 7-in. and upwards.

‡ The heads of the 7, 9, 16, and 40-prs. only are attached to the body in this manner. 4 screws are used in the 7 and 9-prs., 6 for 16-pr., and 8 for 40-pr. Plain rivets are used for the 64-pr. and upwards.

§ At this stage, 64-pr. shells and upwards are placed in a lathe, and the extractor holes bored in the head, and afterwards bushed with tin, the bushes secured with solder.

|| The heads of the 7, 9, 16, 25, and 40-prs. only are painted red; all other calibres are painted black.

TRACTION.

BY

MAJOR W. KEMMIS, R.A.

In a previous paper, "Principles of Construction of Wheels and Axles," ("Proceedings, R.A. Institution," Vol. VIII. p. 369), the relations between the forces which act upon the wheel and axle when upon the point of motion have been stated as follows:—

W = half weight of axle and load,
P = traction, or moving power, its direction making an angle β with the horizontal,
R = resultant of P and W, its direction making an angle θ with the vertical,
W' = weight of the wheel,
R' = resultant of R and W', its direction making an angle θ' with the vertical,
ϕ = limiting angle of resistance between the pipe-box and axletree-arm,
γ = angle of slope of the ground,
AC' = radius of the pipe-box,
BC' = radius of the wheel.

Then

$$P \cdot \cos\beta = R \cdot \sin\theta, \quad \ldots\ldots (1)$$

$$P \cdot \sin\beta + R \cdot \cos\theta = W, \quad \ldots\ldots (2)$$

$$R \cdot \sin\theta = R' \cdot \sin\theta', \quad \ldots\ldots (3)$$

$$R \cdot \cos\theta + W' = R' \cdot \cos\theta', \quad \ldots\ldots (4)$$

$$\sin\theta = \frac{AC'}{C'B} \cdot \frac{\sin\theta' \cdot \sin\phi}{\sin(\theta' - \gamma)} \quad \ldots\ldots (5)$$

Proceeding from these equations to obtain the value of P; by combining (1) with (2),

$$\sin\theta = \frac{P \cdot \cos\beta}{\sqrt{W^2 + P^2 - 2P \cdot W \cdot \sin\beta}}, \quad \ldots\ldots (1')$$

and (3) with (4),

$$\frac{\cos\theta'}{\sin\theta'} = \frac{R\,.\cos\theta + W'}{R\,.\sin\theta}, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2')$$

while, from (5),

$$\frac{\cos\theta'}{\sin\theta'} = \frac{C'B\,.\sin\theta\,.\cos\gamma - AC'\,.\sin\phi}{C'B\,.\sin\theta\,.\sin\gamma} \ldots\ldots\ldots\ldots\ldots\ldots (3')$$

Combining, then, equation (2′) with (3′),

$$\frac{R\,.\cos\theta + W'}{R\,.\sin\theta} = \frac{C'B\,.\sin\theta\,.\cos\gamma - AC'\,.\sin\phi}{C'B\,.\sin\theta\,.\sin\gamma};$$

and substituting in this for $R\,.\cos\theta$ its value in (2), for $R\,.\sin\theta$ its value in (1), and for $\sin\theta$ its value in (1′),

$$\frac{W - P\,.\sin\beta + W'}{P\,.\cos\beta} = \frac{\cos\gamma}{\sin\gamma} - \frac{AC'}{C'B}\cdot\frac{\sin\phi}{\sin\gamma}\cdot\frac{\sqrt{W^2 + P^2 - 2P\,.\,W\,.\sin\beta}}{P\,.\cos\beta};$$

from which

$$\begin{aligned} &P^2\left\{C'B^2\,.\cos^2(\beta-\gamma) - AC'^2\,.\sin^2\phi\right\} \\ &\quad + 2P\left\{AC'^2\,.\sin^2\phi\,.\sin\beta\,.\,W - C'B^2\,.\cos(\beta-\gamma)\sin\gamma\,(W+W')\right\} \\ &\quad = AC'^2\,.\sin^2\phi\,.\,W^2 - C'B^2\,.\sin^2\gamma\,(W+W')^2, \end{aligned}$$

and therefore

$$\begin{aligned} P = {} & \frac{AC'\,.\sin\phi}{C'B^2.\cos^2(\beta-\gamma) - AC'^2.\sin^2\phi}\cdot\sqrt{C'B^2\{(W+W')^2\sin^2\gamma + W^2.\cos^2(\beta-\gamma) - } \\ & \overline{2W(W+W')\cos(\beta-\gamma)\sin\gamma\,.\sin\beta\} - AC'^2.\sin^2\phi\,.\cos^2\beta\,.\,W^2} \\ & + \frac{C'B^2.\cos(\beta-\gamma)\sin\gamma\,(W+W') - AC'^2\,.\sin^2\phi\,.\sin\beta\,.\,W}{C'B^2\,.\cos^2(\beta-\gamma) - AC'^2\,.\sin^2\phi}; \end{aligned}$$

or

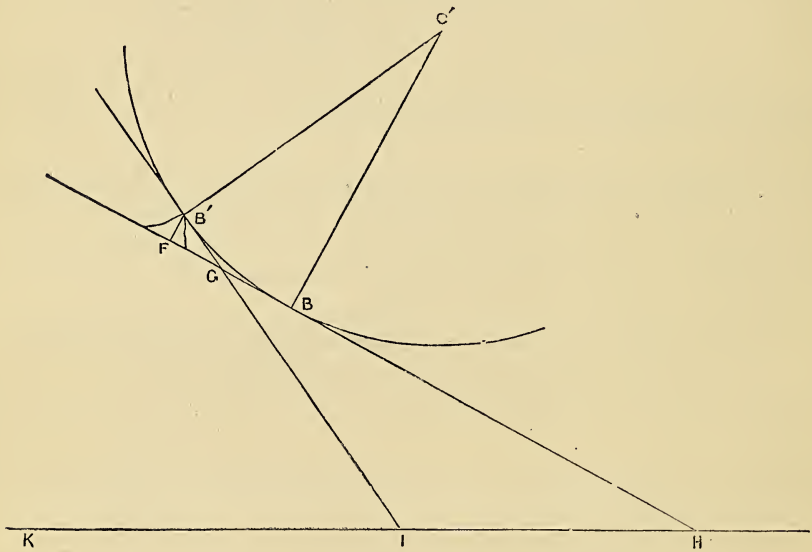
$$\begin{aligned} P = {} & \frac{AC'\,.\sin\phi}{C'B^2.\cos^2(\beta-\gamma) - AC'^2.\sin^2\phi}\cdot\sqrt{C'B^2\{\cos^2\beta.\,W^2 + \sin^2\gamma.\,W'^2 + } \\ & \overline{(\sin^2\gamma + \cos^2\beta - \cos^2(\beta-\gamma)\,WW'\} - AC'^2\,.\sin^2\phi\,.\cos^2\beta\,.\,W^2} \\ & + \frac{C'B^2.\cos(\beta-\gamma)\sin\gamma\,(W+W') - AC'^2\,.\sin^2\phi\,.\sin\beta\,.\,W}{C'B^2\,.\cos^2(\beta-\gamma) - AC'^2\,.\sin^2\phi}; \end{aligned}$$

which, if the co-efficient of friction or $\tan\phi = \mu$, becomes

$$\begin{aligned} P = {} & \frac{AC'\,.\,\mu}{C'B^2(1+\mu^2)\cos^2(\beta-\gamma) - AC'^2.\mu^2}\cdot\sqrt{C'B^2(1+\mu^2)\{\cos^2\beta.W^2 + \sin^2\gamma.W'^2 + } \\ & \overline{(\sin^2\gamma + \cos^2\beta - \cos^2(\beta-\gamma)WW'\} - AC'^2\,.\,\mu^2\,.\cos^2\beta\,.\,W^2} \\ & + \frac{C'B^2(1+\mu^2)\cos(\beta-\gamma)\sin\gamma\,(W+W') - AC'^2\,.\,\mu^2\,.\sin\beta\,.\,W}{C'B^2(1+\mu^2)\cos^2(\beta-\gamma) - AC'^2\,.\,\mu^2} \ldots (A) \end{aligned}$$

If now the wheel meet an obstacle, the effect, when the wheel is on the point of surmounting it, is to change the point of contact with the ground from B to B'; or, in other words, to increase for the instant the slope of the ground by an angle equal to that subtended by the height of the obstacle at the point in which the tangent to the wheel, at the new point of contact, meets the line of the slope of the ground. Thus, in Fig. 1, the wheel meeting an obstacle whose height equals

Fig. 1.



$B'F$, is tantamount to the slope of the ground being increased by the angle $B'GF$, $B'I$ being drawn tangential to the wheel at B'; for

$$\angle GIK = \angle IGH\ (= B'GF) + \angle GHI;$$

or, denoting the angle due to the obstacle by ϵ, and the increased angle of the slope of the ground by γ',

$$\gamma' = \epsilon^* + \gamma,$$

and

$$P = \frac{AC' \,.\, \mu}{C'B^2(1+\mu^2)\cos^2(\beta-\gamma') - AC'^2 . \mu^2} \cdot \sqrt{C'B^2(1+\mu^2)\{\cos^2\beta . W^2 + \sin^2\gamma' . W'^2 + (\sin^2\gamma' + \cos^2\beta - \cos^2(\beta-\gamma')\, WW'\} - AC'^2 . \mu^2 . \cos^2\beta . W^2}$$

$$+ \frac{C'B^2(1+\mu^2)\cos(\beta-\gamma')\sin\gamma'\,(W+W') - AC'^2 . \mu^2 . \sin\beta . W}{C'B^2\,(1+\mu^2)\cos^2(\beta-\gamma')^2 - AC'^2 . \mu^2} \quad \ldots(B)$$

* In the case of the wheel moving down an incline and meeting an obstacle, ϵ is negative.

Let h = the height of the obstacle; then

$$\sin \epsilon \ (= \angle B'C'B) = \frac{\sqrt{2h \,.\, C'B - h^2}}{C'B}, \quad \ldots\ldots\ldots\ldots\ldots (C)$$

which determines the value of ϵ.

Every road, no matter how apparently good, has its imperfections—namely, in its want of perfect smoothness and hardness; and every wheel, no matter how apparently true, in the same manner, has its irregularities of form. These defects oppose the motion of the wheel—in fact, place an obstacle of more or less magnitude continually in its path tantamount to an incline of more or less slope; so that whether on the level or on sloping ground, there is always an angle ϵ to be taken into account.

Suppose the wheel to be on a level road, and the direction of the traction to be parallel to the ground, then in the equation for P the angle $\beta = o$, $\gamma = o$, and $\gamma' = \epsilon$; so that the equation becomes

$$P = \frac{AC' \,.\, \mu \sqrt{C'B^2 (1+\mu^2)(W^2 + \sin^2 \epsilon \,.\, W'^2 + 2 \sin^2 \epsilon \,.\, WW') - AC'^2 \,.\, \mu^2 \,.\, W^2}}{C'B^2 (1+\mu^2) - AC'^2 \,.\, \mu^2}$$

$$+ \frac{C'B^2 (1+\mu^2) \cos \epsilon \,.\, \sin \epsilon \,.\, (W + W')}{C'B^2 (1+\mu^2) - AC'^2 \,.\, \mu^2}. \quad \ldots\ldots\ldots\ldots\ldots (D)$$

Imagine now, under the same circumstances, the road to be most favourable for traction (more so than ever practically met with), opposing but a very slight obstacle to the wheel—one of so small height as only sufficient to call into play the maximum resistance of friction between the pipe-box and the axletree-arm; then the equation approximates to

$$P = \frac{AC' \,.\, \mu \,.\, W}{\sqrt{C'B^2 (1+\mu^2) - AC'^2 \,.\, \mu^2}}. \quad \ldots\ldots\ldots\ldots\ldots (E)$$

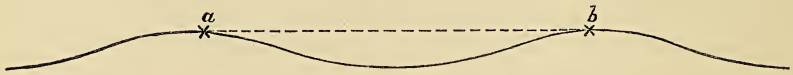
From which it appears that on a hard level road the traction or amount of power necessary to put a wheel in motion is directly proportional to the radius of the pipe-box, the co-efficient of friction between the pipe-box and axle, and the weight of and upon the axle, while it is approximately inversely proportional to the radius of the wheel.

It is evident that this equation (or any former one for P), though deduced from consideration of a single wheel, requires no modification to make it suitable for the traction of any two-wheeled carriage, or four-wheeled carriage with fore and hind wheels of equal height. It is simply necessary to give W its proper value—namely, the weight of the carriage body and its load. If, however, it is required to ascertain the traction of a "lock-under" wagon, in which the fore wheels are of smaller diameter than the hind, it is obvious that the traction of the fore and hind carriage must be calculated separately, W being given in each case an appropriate value—namely, that proportion of the weight of the carriage body and load borne by the particular pair of wheels; the total traction being then taken as the sum of that of the parts.

Applying, in this manner, the formula for P to wagons, one or two inferences may be drawn from it.

In the first place, it is apparent that the distance between the axles never enters the question; that is to say, their distance apart does not affect the traction. (If it was granted that the surface of the road upon which the wagon was destined to travel was, in its length, uniformly wavy—as in Fig. 2—the distance apart of the axles might be

Fig. 2.



suited to the particular length of wave, but to no other. Thus, it would obviously be bad to have the distance apart of the axles the same as the distance, *ab*, from one wave to the other, because in that case both the fore and hind carriage wheels would be ascending at the same time, causing a maximum traction, and at the next instant both descending, causing a minimum. Manifestly, in this case, the best length between the axles would be $\frac{1}{2}ab$, so that one pair of wheels would always be descending, and therefore their traction decreasing, when the other pair were ascending, and therefore their traction increasing.)

In the next, that the distribution of the weight over the axles should, in a "lock-under" wagon, be as the radii of the wheels. Practically, rather less than this should be thrown upon the fore-wheels, because the obstacles to their traction are usually greater than to that of the hind wheels, due to their first meeting the obstacles, and, in passing over them, reducing their height for the hind. In an "equirotal" wagon, the same reason for throwing rather less weight on the fore than on the hind wheels holds equally good: setting, however, this point aside, it appears from the formula that in such a wagon it is a matter of indifference how the load is distributed over the axles; and this would practically be true was it not for the yielding nature of most roads permitting the weight to sink the wheels into them, which must occur to a greater extent if the weight is thrown mainly upon one pair of wheels—*i.e.* upon two points of support, instead of distributed more equally over four.

Equation (*A*) may be made more simple by supposing the direction of the traction to be parallel to the ground: thus making $\beta = \gamma$,

$$P = \frac{AC'.\mu\sqrt{C'B^2(1+\mu^2)(\cos^2\gamma\,.\,W^2 + \sin^2\gamma\,.\,W'^2) - AC'^2\,.\,\mu^2\,.\,\cos^2\gamma\,.\,W^2}}{C'B^2(1+\mu^2) - AC'^2\,.\,\mu^2}$$

$$+ \frac{\sin\gamma\,\{C'B^2(1+\mu^2)(W+W') - AC'^2\,.\,\mu^2\,.\,W\}}{C'B^2(1+\mu^2) - AC'^2\,.\,\mu^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (F)$$

The resistance which an obstacle of even small height offers to traction deserves to be noticed. It is measured, as already shewn, by the increase which for the instant it adds to the slope of the ground. Suppose, for illustration, a 5-ft. wheel to meet an obstacle $\frac{1}{16}$ in. in height. By equation (*C*),

$$\sin\epsilon = \cdot 0645,$$

$$\text{and } \therefore\ \epsilon = 3^\circ\ 45' \text{ (very nearly).}$$

If the obstacle be $\frac{1}{8}$ in. in height, $\epsilon = 5^\circ\ 14'$; if $\frac{1}{4}$ in., $\epsilon = 7^\circ\ 24'$; if $\frac{1}{2}$ in., $\epsilon = 10^\circ\ 28'$; and if 1 in., $\epsilon = 14^\circ\ 50'$.

Thus, to make a carriage which has the ordinary field wheel pass an unyielding obstacle of only 1 in. in height, the horses have for the instant to put forth as much power as would be required to move the same carriage on an incline of about 15°.

The smaller the carriage wheel, the worse it is for passing over an obstacle. Thus, suppose it be a wheel 3 ft. 4 ins. instead of 5 ft. in diameter which meets the obstacle $\frac{1}{2}$ in. in height, and ϵ becomes $12^\circ\ 50'$ instead of $10^\circ\ 28'$, while in the case of the obstacle 1 in. in height it becomes $18^\circ\ 12'$ instead of $14^\circ\ 50'$. From this, setting aside the fact that the traction on the level is inversely proportional to the radius of the wheel, the evil of giving a carriage a low front wheel is evident.

In the 9-pr. M.L.R. gun-carriage and limber, Mark II. (packed),

$$AC' = 1{\cdot}38 \text{ ins.},$$
$$C'B = 30 \text{ ins.},$$
$$W = 3032 \text{ lbs.},$$
$$W' = 920 \text{ lbs.}$$

Taking $\mu = {\cdot}01$, and inserting these values in equation (E), or—what is sufficiently near for all practical purposes—in the modification of it, $P = \frac{AC' \cdot \mu \cdot W}{C'B}$, the traction of the carriage on the level in a direction parallel to the ground is found to be equal to 1·426 lbs.

This, in the usual direction of the traces—namely, at an angle of $6\frac{1}{2}^\circ$ with the horizontal—amounts to 1·448 lbs. Now, as a matter of fact, far greater power than this is required to move the carriage on even the best road, and the apparent discrepancy is simply due to the imperfections of the road and the wheels, which oppose a constant resistance to the motion of the latter; in fact—as mentioned in a former place—whether the carriage is on the level or on an incline, there is always an angle ϵ, depending in amount upon the nature of the road, to be taken into account.

It is in consequence of this that the inclination of $6\frac{1}{2}^\circ$ is given to the traces; and giving this to the line of traction is as much as saying that the average obstacle to the motion of the carriage on the usual nature of road it has to travel over (whether level or inclined), is one whose height will give an angle $\epsilon = 6\frac{1}{2}^\circ$.

In this view, if in equation (B) γ be made $= o$, and $\gamma' = \epsilon\ (= \beta)$, the true traction, under average circumstances on the level, will more nearly be arrived at. Thus

$$P = \frac{AC' \cdot \mu \sqrt{C'B^2 (1+\mu^2)(\cos^2\epsilon \cdot W^2 + \sin^2\epsilon \cdot W'^2) - AC^2 \cdot \mu^2 \cdot \cos^2\epsilon \cdot W^2}}{CB^2 (1+\mu^2) - AC^2 \cdot \mu^2}$$
$$+ \frac{CB^2 \cdot (1+\mu^2) \sin\epsilon (W + W') - AC^2 \cdot \mu^2 \cdot \sin\epsilon \cdot W}{CB^2 (1+\mu^2) - AC^2 \cdot \mu^2},$$

which, for all practical purposes, may be modified to

$$P = \frac{AC'\mu \,.\, W.\cos\epsilon}{C'B} + (W + W')\sin\epsilon;$$

$$\therefore\ (\epsilon = 6\tfrac{1}{2}^\circ)\ P = \frac{41{\cdot}5696}{30} + 447{\cdot}3664$$

$= 448{\cdot}7187$, or with a team of 6 horses 74·7864 lbs. per horse.

In the 16-pr. M.L.R. gun-carriage with limber, Mark II. (packed), $W = 3665$ lbs. and $W' = 1000$ lbs.; therefore, under the same circumstances,

$$P = \frac{50{\cdot}8482}{30} + 528{\cdot}0780$$

$=$ 529·7729 lbs., or with a team of 6 horses 88·2955 lbs. per horse: and with a team of 8 horses 66·2216 lbs. per horse.

That is, the traction of the 16-pr. gun-carriage is to that of the 9-pr. as 1·18 : 1.

In the foregoing remarks the traction has been considered as applied at the axle, its particular point of application there being determined by the equation $CE = \frac{\sin\phi}{\sin\theta} \,.\, AC$ (see "Proceedings, R.A. Institution," Vol. VIII. p. 371), where CE is the vertical distance of the point below the centre of the axle, and AC the radius of the latter, while $\sin\theta = \frac{P\cos\beta}{\sqrt{W^2 + P^2 - 2PW\,.\,\sin\beta}}$ by (1′).

In practice, the traction is usually from the splinter-bar; a consequence of which is that in a wagon fitted with frame shafts hinged to the bar a strain is thrown upon the connecting parts of the fore and hind carriages, and in a cart or limbered wagon with fixed shafts a pressure upon the shaft horse's back equal to $P \,.\, \frac{a}{b}$, where a and b are perpendiculars let fall from the point of application of P, when considered as applied at the axle, respectively upon the direction of P applied at the splinter bar and upon the vertical drawn through the positions of the tugs on the shafts.

In the 9 and 16-pr. limber, Mark II., neglecting the small distance CE—that is, taking the centre of the section of the axle-arm, at the shoulder, as the point of application of P when applied at the axle—the distance $a = 8\frac{3}{4}$ ins. and $b = 7$ ft. 8 ins.; therefore $\frac{a}{b} = {\cdot}095$. Or, to take particular cases, if $P = 448{\cdot}7187$ lbs.—as in the example of the 9-pr. gun-carriage above given—the pressure on the horse, due to the traction being from the splinter-bar, equals 42·628 lbs.;* while if $P = 529{\cdot}7729$ lbs.—as in the example of the 16-pr. gun-carriage—the pressure on the horse from the same cause equals 50·328 lbs.*

Woolwich,
December, 1874.

* In addition to the constant pressure of about 60 lbs. due to his bearing a portion of the weight of the carriage.

NOTES

ON THE

SIEGE EXPERIMENTS AT EASTBOURNE.

BY

MAJOR W. H. WARDELL, R.A.

THE Special Committee on Siege Batteries chose for the scene of their operations a wide and flat waste, formed by successive deposits of shingle beach, situated about two miles from Eastbourne, in the direction of Pevensey and Hastings, and admirably adapted for a shell range. The chief and almost only drawback arose from the fact that the earth required for the target battery and splinter-proofs had to be transported from about a mile inland. This was done by the temporary line of railway laid down by the Royal Engineers, which connected by means of a branch with the London, Brighton, and South Coast system. The rolling-stock consisted of some of the light trucks originally intended for the Gold Coast expedition, drawn by "steam sappers"—which latter are available either for road or rail.

Between Nos. 65 and 66 Martello towers on the beach, an experimental siege battery of four gun-portions was thrown up by working parties of Engineer recruits from Chatham. This constituted the target (see Plate II.), and was provided with magazine, shell-recess, and passages. The nature of the ground did not permit of this battery being "half-sunken," so it was given a command of about 7 ft. 6 ins., and, to save transport of earth, was composed partly of shingle, covered with 4 ft. of stiff clay, and revetted with sand-bags—some filled with earth and some with shingle. Only Nos. 3 and 4 gun-portions were pierced with embrasures, of the bottle-neck shape—one being simply revetted with sand-bags, and the other having the cheeks covered with hides as well. The plan will best show the details of the trace, which gave 24 ft. thickness of parapet, with only a shallow ditch scooped out of the shingle. It will be seen that in front of each of Nos. 1 and 2 gun-portions a semicircular sweep was given to the trace, leaving a minimum thickness of 24 ft. of earth in front of each portion, measured at right angles to the crest line. A screen of shingle 14 ft. thick was thrown up in front of Nos. 3 and 4 gun-portions, revetted in rear with sand-bags. A second section of screen of less thickness was afterwards added to cover the magazine in the right epaulment.

In rear of the target battery a series of splinter-proofs was thrown up, to ascertain the relative values of the protection afforded by various descriptions of roofs.

The sections of roof were as follows:—

(*a*) Oak timbers, 9-ins. deep, covered with 3 ft. thickness of earth.
(*b*) Fir " " " " " "
(*c*) " " " with 3-in. planks, " "
(*d*) " " " " 24-lb. rails, " "
(*e*) 3-in. deals, with 1 thickness of 24-lb. rails, " "
(*f*) " " 2 thicknesses " " "
(*g*) 36-lb. rails, one end overlapping, with sleepers, " "
(*h*) 72-lb. " double-headed, " " "

Over part of the above, 3 ft. of additional earth was afterwards placed, making 6 ft. in all.

Three attacking batteries—"A," "B," and "C"—were thrown up at distances, inland, from the target battery of 1793, 1713, and 1452 yds. respectively. The armament of each consisted of:—

1 8-in. wrought-iron R. howitzer.
1 64-pr. " R.M.L. gun.
1 40-pr. " " "

Tower No. 68 stands on a hill about a mile inland, being considerably larger than the towers along the beach, and having a moat around it. This hill served as a natural parapet for battery "A"; while it necessitated laying the guns without seeing the object aimed at, and afforded an excellent opportunity for the employment of curved fire. Battery "B," on the side of the hill, gave a direct plunging fire. Battery "C" was on the same level as the target battery, and gave direct fire.

The following platforms were under trial, viz:—

	ft. ins. ins.		ft. ins. ins.
Common ground platforms, sleepers	18 × 9 × 9,	planks	10 × 9 × 4½
" " " "	18 × 9 × 9,	"	10 × 9 × 3
" " " "	15 × 9 × 3,	"	9 × 9 × 3

Clerk's platforms, service pattern, were also used.

On 29th October thirteen preliminary rounds of plugged shell filled with shingle were fired from batteries "B" and "C," in order to obtain the correct range. That afternoon was very wet, and the slippery clay in which the platforms of "B" battery were laid increased the natural "liveliness" of the 8-in. R. howitzer, so that finally its carriage recoiled off the platform, and at the close of the firing was left embedded in the mud.

The formal opening of the experiments took place on 30th October, in the presence of H.R.H. the Commander-in-Chief and a large number of officers.

The following table may prove useful for reference:—

	Weight of gun.	Charges fired.	Weight of common shell.	Bursting charge.	Weight of Carriage.
	cwt.	lbs.	(mean) lbs.	lbs. ozs.	cwt.
40-pr. R.M.L.	38	7 2	40	2 10	30
64-pr. "	64	10 3	64	6 14	32
8-in. R. howitzer ...	46	10 8 7 6 5 3½	180 150	14 0 16 0	42 and 34

In giving the results of each day's work, I have arranged the rounds fired from each nature separately, for the sake of simplicity; the precise order of firing will be seen by the general number of the round.

First Day's Firing.

(Friday, 30th Oct. 1874.)

From battery "C," 1452 yds. range; "direct" fire; common shell, with R.L. percussion fuze.

Gen. No. of round.	Nature of ordnance.	Charge.	Elevation.	Effect on target battery (shell burst, &c.)
		lbs.	° ′	
14	40-pr. R.M.L.	7	2 36	Crest of parapet; crater 8′ × 7′ × 3′ deep.
15	"	"	"	50 yds. over.
16	"	"	"	Ridge of screen; small crater 18″ deep.
17	"	"	"	Blind; struck screen.
18	"	"	"	On top of screen; crater 2′ deep.
19	64-pr. R.M.L.	10	2 20 to 2 30	110 yds. under.
20	"	"	"	110 yds. over.
21	"	"	"	Cut away bannerol on top of battery.
22	"	"	"	Foot of screen.
23	"	"	"	In battery; cut away flagstaff by splinter.
24	8-in. R. howitzer	7	10 30 to 10 40	Blind; 50 yds. under.
25	"	"	"	Section *g* of splinter-proof; four frames damaged, and five capsills broken; end of rails down; three uprights driven in on front side of gallery.
26	"	"	"	Blind; foot of screen.
27	"	"	"	75 yds. under; burst after graze.
28	"	"	"	In splinter-proof.
29	"	"	"	In battery; burst after graze, making long shallow crater 14′ × 3′ × 18″ deep.
30	"	"	"	45 yds. over; burst on graze.
31	"	"	"	35 yds. over.
32	"	"	"	Struck interior crest of left gun-portion, carrying away one sand-bag from interior crest, and then burst 3′ from ground; damaged both cheeks of embrasure. Numerous grazes of splinters in rear of traverse, as well as of gun-portion.
33	"	"	"	In splinter-proof; breached side of section *h*, carrying away four baulks 3″ by 9″, filling passage with earth; stancheons of two frames carried away; crater 14½′ × 11′.

Note.—In all measurements of craters given, the first figure denotes length of crater at surface, measured across the battery; the second figure breadth of crater at surface, measured parallel to the crest line; and the third dimension gives the maximum depth.

The recoil of the 8-in. howitzer was rather violent, although means had been taken to raise the side pieces of the Clerk's platform from which it was fired; the trail plank was more than once broken. It was intended to have fired from the howitzer in "B" battery, but the continued heavy rain of the previous night had caused the carriage to sink so deeply in the mire that it was left there for the day.

Second Day's Firing.

(4th November, 1874.)

From "B" battery, 1713 yds. range; 32 rounds of shrapnel shell were fired with full charges from 64-pr. and 40-pr. R.M.L. guns, of which 13 were with time fuzes, and the remainder with R.L. percussion fuzes. General Nos. 34 to 65.

It seems unnecessary to give a tabular statement of this firing, the total effects of which were inconsiderable. Round No. 42, from 40-pr. gun, burst in battery, killing the No. 1 of the gun, breaking 2 spokes and 1 felloe of left wheel; splinter in front transom of carriage, and 5 splinters and 22 hits in targets behind; interior crest and cheeks of embrasure damaged in two places. The next round, No. 43, from 64-pr. gun, destroyed sand-bags at corner of merlon; 2 splinters and 8 hits in targets. Round No. 45 wounded 1 man, and put 2 splinters in targets behind. This practice gave additional proof that shrapnel, fired with percussion fuzes, is of little or no use against earthworks; with time fuzes, some damage might be done to the defenders, if we could ensure the shell bursting close over the top of the battery—but this is not so easily done. The 40-pr. shrapnel seemed too weak, as three of them burst in the gun. This was the only portion of the programme of shrapnel-fire which the Committee thought it necessary to carry out.

Third Day's Firing.

(5th November, 1874.)

Common shell, firing from "B" battery; fuzes used, R.L. percussion with full charges, and "sensitive" fuze with reduced charges.

Portions fired at .. { No. 3 with 64-pr.
" 4 " 40-pr.

except rounds 92, 94, and 96 at No. 1 gun-portion.

Gen. No. of round.	Nature of ordnance.	Charge.	Elevation.	Effects on target battery (shell burst, &c.)
		lbs.	° ′	
66	64-pr. R.M.L.	10	3 15	150 yds. over.
68	"	"	3 10	50 yds. over.
70	"	"	3 7	Struck foot of screen, and burst after graze; destroyed 2 rails of temporary railway.
72	"	"	"	In battery; fell in old crater.
74	"	"	"	Foot of screen.
76	"	"	"	No. 3 gun-portion; crater 11′ × 15′ × 4′ deep; blew in right cheek of embrasure, entirely closing it.
78	"	"	"	Exterior slope of battery; partly re-opened embrasure.
80	"	"	"	In battery; killed Nos. 1, 2, 3, and 4 of gun detachment; cut away right angle of embrasure; 9 large splinters and a quantity of debris lay in gun-portion No. 3.
82	"	3	9 40	300 yds. under; noisy.
84	"	"	11 0	Exterior slope of battery; crater 8½′ × 6′ × 3′ deep.
86	"	"	"	200 yds. short.
88	"	"	12 0	Struck 75 yds. short; blind.
90	"	"	12 30	200 yds over.
92	"	10	3 7	Struck top of battery; burst after graze.
94	"	"	"	In battery; crater 8′ × 9′ × 3′ deep.
96	"	"	"	Grazed right of screen.

Third Day's Firing (continued.)

Gen. No. of round.	Nature of ordnance.	Charge.	Elevation.	Effects on target battery (shell burst, &c.)
		lbs.	° ′	
67	40-pr. R.M.L.	7	3 25	Top of screen; crater 8′ × 8½′ × 2′ deep.
69	"	"	"	Between battery and splinter-proof, in rear target.
71	"	"	"	50 yds. over.
73	"	"	"	In battery; blind; penetrated 11′, cutting quite a cavern, 3′ × 6′ in greatest section.
75	"	"	"	30 yds. over, on shingle; grazed splinter-proof to depth of 6″.
77	"	"	"	In screen.
79	"	"	"	Do.
81	"	"	"	50 yds. over.
83	"	"	"	In screen.
85	"	"	"	Entered exterior slope of parapet, causing a small open crater 2′ × 2½′ in area; but when dug out next day, was found to have burst with the effect of an undercharged mine 8½′ × 7′ in area.
87	"	"	"	In battery; burst after penetration, and cut down bannerol; damaged both cheeks of embrasure in No. 4 gun-portion, partly closing it.
89	"	"	"	50 yds. over.
91	"	"	"	Exterior crest of battery; damaged right cheek of embrasure No. 4 gun-portion, completely closing it.
93	"	"	"	In exterior slope.
95	"	"	"	Grazed splinter-proof, and burst.
97	"	"	"	In screen, cutting through 11′ of shingle, and displacing 27 sand-bags.

Fourth Day's Firing.

(6th November, 1874.)

Direct fire, with common shell, from "C" battery, at 1452 yds. range; fuzes as before. Object aimed at, No. 1 gun-portion (no embrasure).

Gen. No. of round.	Nature of ordnance.	Charge.	Elevation.	Effects on target battery (shell burst, &c.)
		lbs.	° ′	
98	64-pr. R.M.L.	10	2 15	150 yds. over.
100	"	"	2 20	50 yds. over.
102	"	"	2 15	In battery; burst after graze.
104	"	"	"	In battery; crater 7′ × 9′ × 3′ deep.
106	"	"	"	50 yds. over.
108	"	"	2 12	Do.
110	"	"	"	Exterior crest of battery; 2 men wounded; increased crater made by round 104 to 16′ × 9′ × 3½′ deep.
112	"	"	"	40 yds. short.
114	"	"	"	In battery; increased crater made by rounds 104 and 110 by 5′ in length, till it extended to within 3′ of interior crest; 2 men killed, and one badly wounded; four splinters struck left merlon of gun emplacement; 3 hits on targets in rear, and 1 prop broken.
116	"	"	"	30 yds. short.

Fourth Day's Firing (continued.)

Gen. No. of round.	Nature of ordnance.	Charge.	Elevation.	Effects on target battery (shell burst, &c.)
		lbs.	° ′	
99	40-pr. R.M.L.	7	2 35	Interior crest of traverse; graze 1½′ × 1′ × 5″ deep.
101	"	"	"	In battery; only a scoop.
103	"	"	"	Exterior slope of battery; crater 9′ × 3′ × 3′ deep.
105	"	"	"	60 yards over.
107	"	"	"	In battery; 3 men killed and 1 badly wounded.
109	"	"	"	Exterior slope of battery; crater 12′ × 6′ × 2½′ deep.
111	"	"	"	On splinter-proof, section *b*; crater 4½′ × 1′ × 2′ deep; no damage inside.
113	"	"	"	200 yds. over; in sea.
115	"	"	"	Exterior crest of battery; crater 6′ × 6′ × 1½′ deep.
117	"	"	"	100 yds. over.
118	"	2	9 0	40 yds. short.
119	"	"	9 30	100 yds. over.
120	"	"	9 15	50 yds. over.
121	"	"	9 0	60 yards short.
122	"	"	"	On splinter-proof; crater closed by falling shingle.
123	"	"	8 55	On splinter-proof; blind.
124	"	"	8 50	Exterior crest of splinter-proof; crater 6′ × 4½′ × 1¾′ deep, at extreme end of section *d*; interior not injured.
125	"	"	8 40	75 yds. short.
126	"	"	8 45	Foot of exterior slope of battery; blind.
127	"	"	"	In battery; scoop on superior slope 7′ × 1′; cut down bannerol by splinter; Nos. 2, 3, and 5 of gun killed; 5 hits on targets in rear, and 1 sand-bag displaced.

The week ending 14th November was occupied in repairing the damage done to the battery, &c., and also in erecting a short additional section of screen to cover the magazine in the right epaulment. Over part of splinter-proof 3 ft. more earth was placed, making in all 6 ft. above the rails, &c.

On Tuesday, 17th November, the regular programme of common shell fire from the 8-in. R. howitzer was commenced, and excited much interest, as was evinced by the presence of the Director of Artillery, the Director-General of Fortifications, the Deputy-Adjutants-General of Artillery and Engineers, and a large gathering of officers, chiefly of the scientific arms. The weather during this week, however, was most unfavourable; a strong wind blew obliquely across the range on 18th and 19th, and rain fell on all three days.

Fifth Day's Firing.

(17th November, 1874.)

From "B" battery, at 1713 yds. range; fuzes, R.L. percussion for high charges, sensitive percussion for low charges. (Rounds 139 to 143, inclusive, were fired from "A" battery, 1793 yds.)

Gen. No. of round.	Nature of ordnance.	Charge.	Elevation.	Effects on target battery (shell burst, &c.)
		lbs.	° ′	
128	64-pr. R.M.L.	10	3 15	120 yds. over.
129	"	"	3 12	50 yds. over.
130	"	"	3 10	Exterior slope of screen.
131	"	"	"	60 yds. over.
132	"	"	3 8	At foot of screen.
133	"	"	3 10	Superior slope of battery; 3 men wounded; 10 hits on targets in rear.
134	"	"	"	Exterior crest of battery; crater 9′ × 3′ × 2′ deep; 4 men killed; 1 hit on target in No. 3 gun-portion.
135	"	"	"	Blind; struck top of battery, and afterwards found in rear of splinter-proof.
136	"	"	"	On screen.
137	"	"	"	Burst in air, after grazing top of battery.
138	8-in. R. Howitzer.	10	8 30	Grazed 50 yds. short, and burst over battery, without doing damage; recoil so violent that the piece jumped sideways off the Clerk's platform.
139	"	5	18 0	250 yds. short; 20′ left.
140	"	"	20 0	On splinter-proof; crater 14′ × 12′ × 3½′ deep; broke 1 stancheon inside, and forced in the sheeting (section *f*, 6′ of earth).
141	"	"	"	100 yds. short.
142	"	"	"	In screen; crater 12′ × 12′ × 3′ deep.
143	"	"	21 0	120 yds. over; burst on the sea.
144	"	"	20 0	2 yds. beyond splinter-proof.
145	"	"	19 30	50 yds. over.
146	"	"	19 15	On splinter-proof; crater 10′ × 5′ × 1½′ deep; no damage inside.
147	"	"	19 0	30 yds. over.
148	"	"	18 45	100 yds. short.
149	"	"	"	Struck exterior crest of parapet, making a crater on top 12′ × 8½ × 3′ deep.
150	"	"	18 51	170 yds. short.
151	"	"	"	110 yds. short.

During the night of the 17th a large fire broke out in a timber yard at Eastbourne, spreading to a brewery adjoining. The gunners and sappers were present, and rendered valuable aid in putting out the fire; but, as they did not get to bed till about 3 a.m., practice could not go on at the usual hour of 9 o'clock, and the batteries were not manned till after dinner on the 18th. This delay, and the fact of the range being frequently blocked by fishing boats, caused but little progress to be made.

Sixth Day's Firing.

(18th November, 1874.)

Practice from "B" battery (1713 yds.), with 8-in. R. howitzer; 180-lb. shell; R.L. percussion fuzes; high wind, blowing at about 45° to range, towards target battery.

Gen. No. of round.	Charge.	Elevation.	Effects on target battery (shell burst, &c.)
	lbs.	° ′	
152	8	10 0	70 yds. short, blind; the gun, after recoiling up the wedges, ran up violently against the hurter, and fell over on its muzzle, with trail in the air.
153	"	10 20	Foot of screen; gun recoiled off platform.
154	"	10 30	Foot of screen; blind.
155	"	11 0	120 yds. short. N.B.—Fired from "A" battery, with sensitive fuze.

This afternoon, as soon as darkness had set in, seven rounds of "star-shells" were fired from the 8-in. R. howitzer, at 40° elevation, with charges of 2 lbs. and 3½ lbs. They were fired from "B" battery, and fell upon the shingle at from 500 to 200 yds. short of the target battery. Very few of the magnesium stars in each shell ignited properly, but those which did burn gave a very brilliant light. The target battery was not rendered visible; but it is of course impossible to say what the effect would have been had all the stars ignited, and the projectiles ranged well up to the object.

Seventh Day's Firing.

(19th November, 1874.)

Firing with 8-in. R. howitzer, 5-lb. charge, at No. 1 gun-portion and magazine in right epaulment. The first six rounds from battery "A," 1793 yds.; the remainder from battery "B," 1713 yds.

Gen. No. of round.	Weight of shell.	Fuze.	Elevation.	Effects on target battery (shell burst, &c.)
	lbs.		° ′	
163	180	Sensitive.	19 0	Just over splinter-proof; 20′ right.
164	"	"	18 45	Near foot of right screen.
165	"	"	18 48	Foot of exterior slope.
166	"	"	"	60 yds. short.
167	"	"	18 51	100 yds. short.
168	"	"	19 0	50 yds. short.
				[*From battery "B."*]
169	180	Sensitive.	18 45	On top of battery.
170	"	"	"	40 yds. short.
171	"	"	"	30 yds. over.
172	"	"	"	170 yds. over.
173	150	Prussian.	18 10	Interior crest of battery; blind; carried away sand-bags from interior crest for a distance of 5′ × 1½′ × 2¾′ deep, and knocked over one target.
174	"	"	"	100 yds. over.
175	"	"	17 50	170 yds over; blind; in sea.
176	"	"	17 40	100 yds. over; blind; ricochetted on sea.
177	"	Sensitive.	17 20	20 yds. over; crater in shingle 14′ × 14′ × 4¼ deep.
178	"	"	17 10	15 yds. over; 10′ left; passed through top of target in rear.
179	"	"	17 0	Right of splinter-proof.
180	"	"	16 50	30 yds. over.
181	"	"	16 40	Between the screens.
182	"	"	"	In line with splinter-proof.

At the conclusion of the shell practice this day, three rounds of experimental cylindrical carcasses, as proposed by Lieut. O'Callaghan, R.A., were fired from an 8-in. howitzer in "B" battery, at elevations of 25°, 35°, and 40° respectively, with a 3½-lb. charge. These projectiles somewhat resemble the Boxer shrapnel in construction, having a light head attached to a cylindrical body, which is studded to take the rifling in the ordinary manner. The interior is filled with carcass composition, and a small bursting charge placed

on top is intended to blow off the head, and also ignite the contents of the cylinder. The third round ranged nearly up to the target battery, and was the only one which burnt as intended, the others breaking up.

An examination of the tables will show a good deal of uncertainty in the practice made with the 8-in. R. howitzer during this week, even when fired at the same elevation and under precisely similar conditions. Striking examples are afforded by comparing rounds 140 and 141, 149 and 150, 170 and 172, &c. Every round was laid with the utmost care by Captain Fairfax Ellis, R.A., Asst.-Supt. of Experiments at Shoeburyness, and it is difficult to account for the variations alluded to. However, as about two-thirds of the ammunition granted for these trials had now been expended with comparatively indecisive results, and the object being (to quote the programme) "to ascertain the effects of live shells on earthworks, &c., and to obtain the best results from the amount of ammunition expended," the Committee determined to decrease the range, so as to ensure a larger proportion of the shells striking the battery. A fourth firing battery was therefore established at 1000 yds. range, consisting simply of platforms laid upon the shingle, upon which were mounted two 8-in. R. howitzers, and one 64-pr. R.M.L. gun; the latter was mounted on a Clerk's platform, and the howitzers upon ground platforms laid *perfectly level*, German wood wedges being employed, as before, to check the recoil.

Eighth Day's Firing.

(Tuesday, 24th Nov., 1874.)

Direct shell fire at 1000 yds. range; sensitive fuze with 8-in. R. howitzer, and R.L. percussion with 64-pr. R.M.L. gun.

Points aimed at...
- Rounds 186 to 195, No. 3 gun-portion.
- " 196 " 204, " 4 "
- " 205 " 209, right hand corner of No. 2 gun-portion.
- " 210 " 212, magazine in traverse.

Gen. No. of round.	Nature of ordnance.	Charge.	Weight of shell.	Elevation.	Effects on target battery (shell burst, &c.)
		lbs.	lbs.	° ′	
186	8-in.R.howtz.	3½	180	17 0	In screen; crater 12′ × 13′ × 3½′ deep; closed continuation of embrasure (in screen).
187	"	"	"	17 20	25 yds. over.
188	"	"	"	17 10	Foot of splinter-proof.
189	"	"	"	"	Between battery and splinter-proof.
190	"	"	"	17 0	Just cleared crest of parapet on left of gun-portion, and burst on railway, displacing four sleepers and destroying two rails; crater 10′ × 7′ × 1½′ deep.
191	"	"	"	"	Just cleared parapet, passed through target, and burst on shingle behind.
192	"	"	"	16 55	Noisy; just over splinter-proof.
193	"	"	"	16 50	In screen; enlarged crater made by round 186 to 18′ × 14′ × 3½′ deep, extending it to foot of screen.
194	"	"	"	"	Cleared interior crest of parapet, and struck the gun just behind trunnions; made only a dent, and burst, killing No. 1 of gun; numerous splinters on targets in rear.

Eighth Day's Firing (continued.)

Gen. No. of round.	Nature of ordnance.	Charge.	Weight of shell.	Elevation.	Effects on target battery (shell burst, &c.)
		lbs.	lbs.	° ′	
195	8-in. R. howtz.	3½	180	16 50	Exterior slope of battery, cutting away a portion 12′ × 9′.
196	"	"	150	16 0	Foot of splinter-proof.
197	"	"	"	15 50	30 yds. over; 10′ left.
198	"	"	"	15 40	Passed through targets, and burst on graze; crater in shingle.
199	"	"	"	"	50 yds. over.
200	"	"	"	15 30	On top of battery; 15′ right; crater 15′ × 11′ × 4′ deep.
201	"	"	"	"	Between targets and splinter-proof.
202	"	"	"	"	Interior crest of parapet on left of gun-portion; crater 8′ × 4′ × 2′ deep.
203	"	"	"	"	Top of parapet to left of gun-portion, bulging the interior crest and removing several sandbags; double crater 18′ × 9′ and 6′ × 6′ × 3½′ deep.
204	"	"	"	"	Struck top of parapet to left, and burst in gun-portion, killing nearly the whole gun-detachment.
205	64-pr. R.M.L. gun.	10	64	1 30	Exterior slope of parapet (right-hand corner No. 2 gun-portion).
206	"	"	"	"	Exterior slope of parapet.
207	"	"	"	"	Foot of exterior slope of parapet.
208	"	"	"	"	Exterior slope of battery.
209	"	"	"	"	Do. do.*
210	8-in. R. howtz.	3½	150	15 30	Foot of splinter-proof on extreme left flank.
211	"	"	"	"	Between targets and splinter-proof; crater 18′ × 13′ × 3½′ deep.
212	"	"	"	"	Interior crest of traverse; two capsills cracked in magazine below; double crater 21′ × 6′ and 6′ × 6′ × 3½′ deep.

* The effect of the five rounds, 205 to 209, was a cut across the parapet 28 ft. long by 16 ft. in greatest width, and 3 ft. 6 ins. deep at exterior crest. (See section, Plate II.)

NOTE.—When a *double* crater is recorded, the first pair of figures denote roughly the "area of disturbance," and the remaining dimensions refer to the deep crater.

Recoil.—When the wedges were removed, the recoil along the level ground platform was found to be 21 ft., with trail embedded in shingle in rear. With the 180-lb. shell and 3½-lb. charge, the mean recoil up the planes was 2 ft., the foot of each wedge being 7 ft. from centre of wheel when run up; this distance was found to give sufficient power to enable the gun and carriage to run up again into its place against the hurter. With the 150-lb. shell the foot of each wedge was placed 6 ft. from centre of wheel, the distance recoiled up the inclines being still 2 ft. on the average.

NINTH DAY'S FIRING.

(25th November, 1874.)

8-in. R. howitzer; direct shell fire at 1000 yds. range; wind across range, force 3.

Points aimed at .. { Rounds 213 to 222, No. 1 gun-portion.
" 223 " 235, magazine in right epaulment.
" 236 " 248, No. 4 gun-portion.

Gen. No. of round.	Charge.	Weight of shell.	Fuze.	Elevation.	Effects on target battery (shell burst, &c.)
	lbs.	lbs.		° ′	
213	$3\frac{1}{2}$	180	Sensitive.	16 50	Right of splinter-proof.
214	"	"	"	"	40 yds. over.
215	"	"	"	16 30	200 yds. short.
216	"	"	"	"	Right of splinter-proof.
217	"	"	"	"	40 yds. over.
218	"	"	"	16 20	Exterior crest of battery; joint crater with round 220.
219	"	"	"	"	15 yds. over.
220	"	"	"	"	Exterior crest of battery; joint crater with round 218, 14′ × 10′ × $3\frac{1}{2}$′ deep.
221	"	"	"	"	Shell made a scoop on top of battery 6′ × $4\frac{1}{2}$′ × 2′ deep, and burst after it had passed on.
222	"	"	"	"	Interior crest of battery; crater 14′ × $9\frac{1}{2}$′ × $3\frac{1}{2}$′ deep; 3 hits on targets in rear.
223	"	150	"	15 10	Exterior slope of battery; crater not measured.
224	"	"	"	"	15 yds. over.
225	"	"	"	"	Just cleared parapet, and burst at foot of targets in rear.
226	"	"	"	15 5	In epaulment, between magazine passage and interior crest; double crater 16′ × 11′ and 6′ × 6′ × 4′ deep.
227	"	"	"	"	Rear of gun-portion; no damage to gun or detachment, but broke 1 rail and several sleepers.
228	"	"	"	"	Foot of exterior slope of battery; crater not measured.
229	"	"	"	"	Do., do.
230	"	"	"	"	Top of screen.
231	"	"	"	15 10	To right of magazine.
232	"	"	"	"	Exterior slope of battery; crater not measured.
233	"	"	"	"	Top of battery, right epaulment; stopped up passage into magazine, smothering 3 men. (See next round.)
234	"	"	"	"	Joint crater with last round; largest dimensions 15′ × 14′ × 4′ deep.
235	"	"	"	"	Exterior slope of battery; crater not measured.
236	"	180	9 secs. time (unbored).	16 20	40 yds. over; burst 3 secs. after graze.
237	"	"	"	"	50 yds. over; burst on ricochet out to sea.
238	"	"	"	"	In rear of traverse, No. 4 gun-portion.
239	"	"	"	"	Drove in right cheek of embrasure, No. 4 gun-portion, and part of interior crest, displacing 7 rows of sand-bags; also sand-bags at corner of left cheek, by a splinter; 6 men of gun-detachment killed; crater 16′ × 7′ × $3\frac{1}{2}$′ deep; shell penetrated $12\frac{1}{2}$′ before bursting.
240	6	"	14 tenths.	7 0	Struck 70 yds. short; burst in air after ricochet.
241	"	"	10 "	7 30	Burst in air before graze, 60 yds. short.
242	"	"	12 "	"	Struck screen and burst; gun recoiled off wedges.
243	"	"	14 "	"	In screen.
244	"	"	14 "	"	Blind; struck exterior crest of battery on right of embrasure No. 4 portion, closing it; scoop 14′ long, 8′ greatest width, by 2′ deep; shell found lying across battery.
245	"	"	13 "	"	In splinter-proof; no damage inside.
246	"	"	"	"	Exterior slope of battery. (See next round.)
247	"	"	"	"	Exterior crest of battery; joint double crater with last round $15\frac{1}{4}$′ × $18\frac{1}{2}$′ and 5′ × 13′ × 4′ deep.
248	"	"	"	"	Burst in air, 40 yds. short.

Recoil.—Mean as before, with the $3\frac{1}{2}$-lb. charges; with the 6-lb. charges the gun recoiled 6 ft. up the inclines, a space of 7 ft. intervening between the foot of wedge and centre of wheel; with the higher charges the gun ran up rather violently, and had to be checked by means of handspikes placed in front of the wheels; the hurter was also protected by sand-bags.

The ammunition for the 8-in. R. howitzer had now been all expended, but there remained 50 rounds of common shell for the 64-pr. R.M.L. gun, which the Committee determined to devote to complete the breach in the parapet of No. 2 gun-portion, commenced by the five rounds fired on 24th; and after this had been accomplished, to endeavour to reach the magazine in the traverse between Nos. 3 and 4 gun-portions.

Tenth Day's Firing.

(Thursday, November 26th, 1874.)

Common shell, from 64-pr. R.M.L. gun, 10-lb. charge, R.L. percussion fuzes.

(*a*) Twenty rounds (general Nos. 249 to 268) were fired at $1\frac{1}{2}°$ elevation, from the 1000 yds. range, against the former cut in the right-hand corner of No. 2 gun-portion. Eighteen shells struck the target battery, but three of these were blind. The result was a breach or cut through the parapet, reaching the interior crest, and laying open the gun-portion at the eighteenth round—or the twenty-third, counting the shells previously fired at the same spot. Its width at interior crest was 7 ft. by 2 ft. 9 ins. deep, and at the exterior crest it was 16 ft. wide by 5 ft. deep. Round No. 264 cut down the bannerol. The twenty rounds were fired in half-an-hour. (See section, Plate II.)

(*b*) Ten rounds from "C" battery, 1452 yds. range, were next fired (general Nos. 269 to 278), the bannerol being placed on the traverse immediately above the magazine; elevations, by quadrant, 2° 42′ to 2° 60′. The result was very slight, only one round—No. 278, fired at 2° 51′ elevation—gave a crater on top of battery, $12\frac{1}{2}$ ft. by 4 ft. by $2\frac{1}{2}$ ft. deep. One shell burst in the gun.

The sand-bags of the embrasures in battery "C"—of the bottle-neck shape—frequently took fire, and the gunners had to get into the embrasures to pour buckets of water over them.

(*c*) The remaining twenty rounds (general Nos. 279 to 298) were fired from the 1000 yds. range as before, except that the bannerol over the magazine in traverse was the object aimed at. The result upon the target battery of the concluding thirty rounds was a crater reaching $29\frac{1}{2}$ ft. from the exterior crest, and 20 ft. wide at the junction of the traverse and parapet, the maximum depth being 3 ft. (See section, Plate II.) The magazine below remained uninjured. The damage to the screen extended across its whole width, being 10 ft. wide at exterior, and 20 ft. at interior crest; depth, $1\frac{1}{2}$ ft. inside and $3\frac{1}{2}$ ft. outside.

In reviewing briefly the results of the experiments, it appears that 24 ft. of earth affords a tolerably good protection against the direct fire of rifled

siege guns. Of course, no thickness of parapet would preserve the defenders and their guns from the destructive effect of such a travelling mine as a howitzer shell containing 14 or 16 lbs. of powder, dropped into a gun-portion by plunging or curved fire; but the difficulty is to place it there. The tables show how uncertain was the fire, even at the comparatively low angles at which the 8-in. R. howitzer was fired at Eastbourne, when the piece was laid with the greatest care and skill, and the ranges accurately measured by chain. It is a question whether it may not be possible to trace and to eliminate some of the causes of this uncertainty, which is the more surprising as the howitzer appears to have made very good practice at Shoeburyness.

The sketches of sections through craters show pretty clearly the power of the shells. The deepest craters were made, as would be expected, by the 8-in. howitzer—the maximum depth being 4 ft.—and the effects of the 150-lb. shells, with 16-lb. bursters, would seem slightly greater than those of the 180-lb. shell, containing 14 lbs. of powder; but it is possible that the effect of the extra bursting charge is, to a certain extent, neutralised by the shell having, from its diminished weight, less penetrative power. In estimating the total effect upon the target battery, it must be remembered, not only that the battery was repaired during the experiments, but that only 275 live shell in all were fired against it—including the 40-pr. shells, and the 32 rounds of shrapnel fired on 4th November. It is to be doubted whether this number of rounds was sufficient to give very decisive results. Neither of the magazines constructed in the battery were reached, and the splinter-proof—placed some little distance in rear—was not directly fired at after the first day, when section *g* was broken through by round 25; but 3 ft. of additional earth having been added, the subsequent rounds which struck the bomb-proof failed to do any damage inside. It would probably have been more severely tested had it been closer to the battery. The cut into the interior crest was neatly executed in 23 rounds, but the gun and carriage were quite uninjured, and it does not appear that any harm was done to the detachment; a few more rounds, however, at the same spot would probably have told a different tale.

These trials certainly give additional testimony to the value of the screen, even when the distances are accurately known. The embrasures do not seem to have suffered very seriously; as, although both were closed once or twice, they could easily have been re-opened.

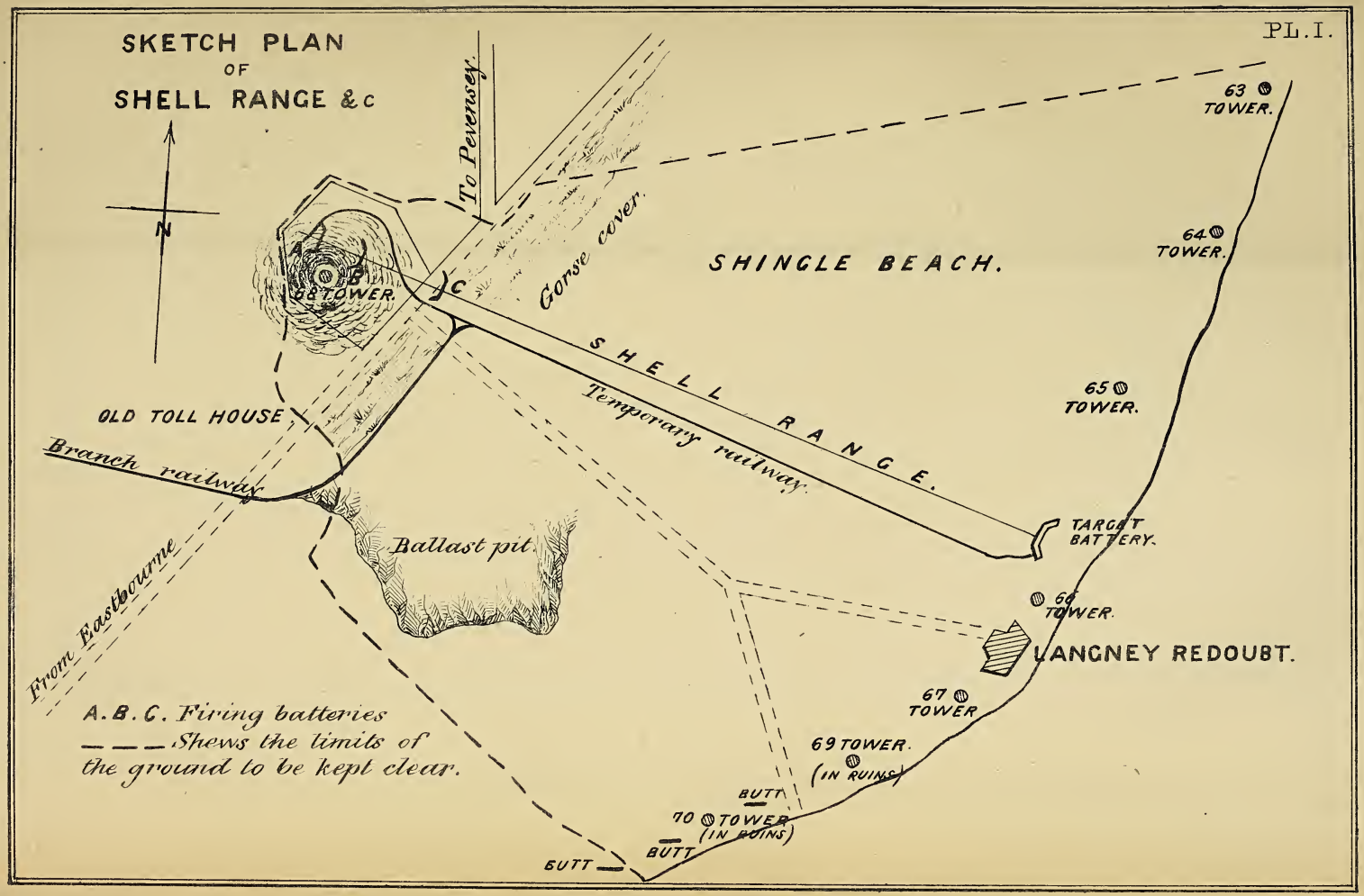
As regards the difficult question of fuzes, it must be remarked that out of 50 rounds of 64-pr. common shell fired on 26th November 8 were blind; showing on that day 16 per cent. of failures for the R.L. percussion fuze, besides one shell which burst in the bore. The trial of the time fuzes as percussion was satisfactory, so far as it went; only one out of the 13 rounds so fired was blind, and those which fairly hit the battery proved very destructive. It appears probable that time fuzes, bored rather long, would enable the shell to penetrate further into earth before bursting than fuzes which act instantaneously, and would therefore produce larger craters; but a more extended trial would be needed to settle the point.

The recoil of the 8-in. R. howitzer is certainly very considerable, and requires some effective control. This can doubtless be supplied by the use of the German wood wedges tried at Eastbourne. It is evident that a perfectly

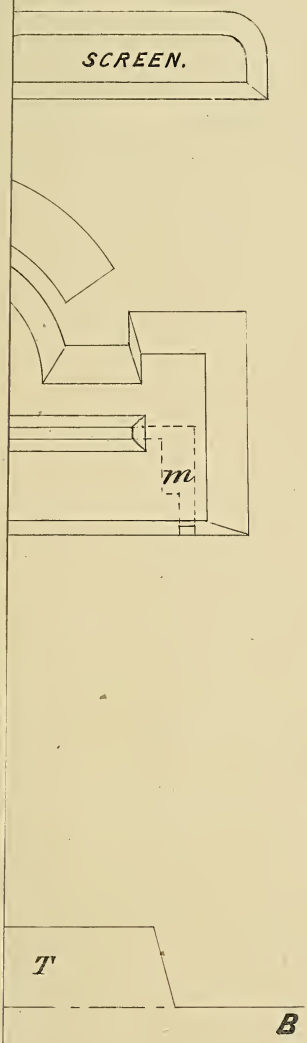
level ground platform to start with has the advantage of keeping the wheels of the carriage on the same plane, however much the trail may be inclined to the axis of the platform.

In the "curved fire" from "A" battery, the line was accurately found by using the sling-scales, slightly modified from the Prussian. They consist simply of two metal bars, graduated alike in plain figures, and horizontally suspended by steel rods with hooks—one beneath the axletree, and the other about half-way down, and underneath the trail. An axis-line is clearly marked down the centre of the platform—or three parallel lines to save traversing the carriage—which axis-line has been laid carefully by pickets, or other means, upon the object to be fired at. As both scales are alike, it is evident that when they are properly adjusted upon the carriage we get the gun correctly laid by bringing any two similar graduations exactly over the line marked on the platform. The Germans give deflection by bringing a *different figure on the rear scale* to correspond on the axis-line with one on the front scale; but the scales in question possess a great simplification in having a small separate graduation on the right of the rear scale, by means of which any required deflection can be given by sliding the scale in its slings, which have clamping screws. We are thus enabled *always* to adjust the same figures on both scales to the axis-line—a decided advantage for rough and ready work in the trenches.

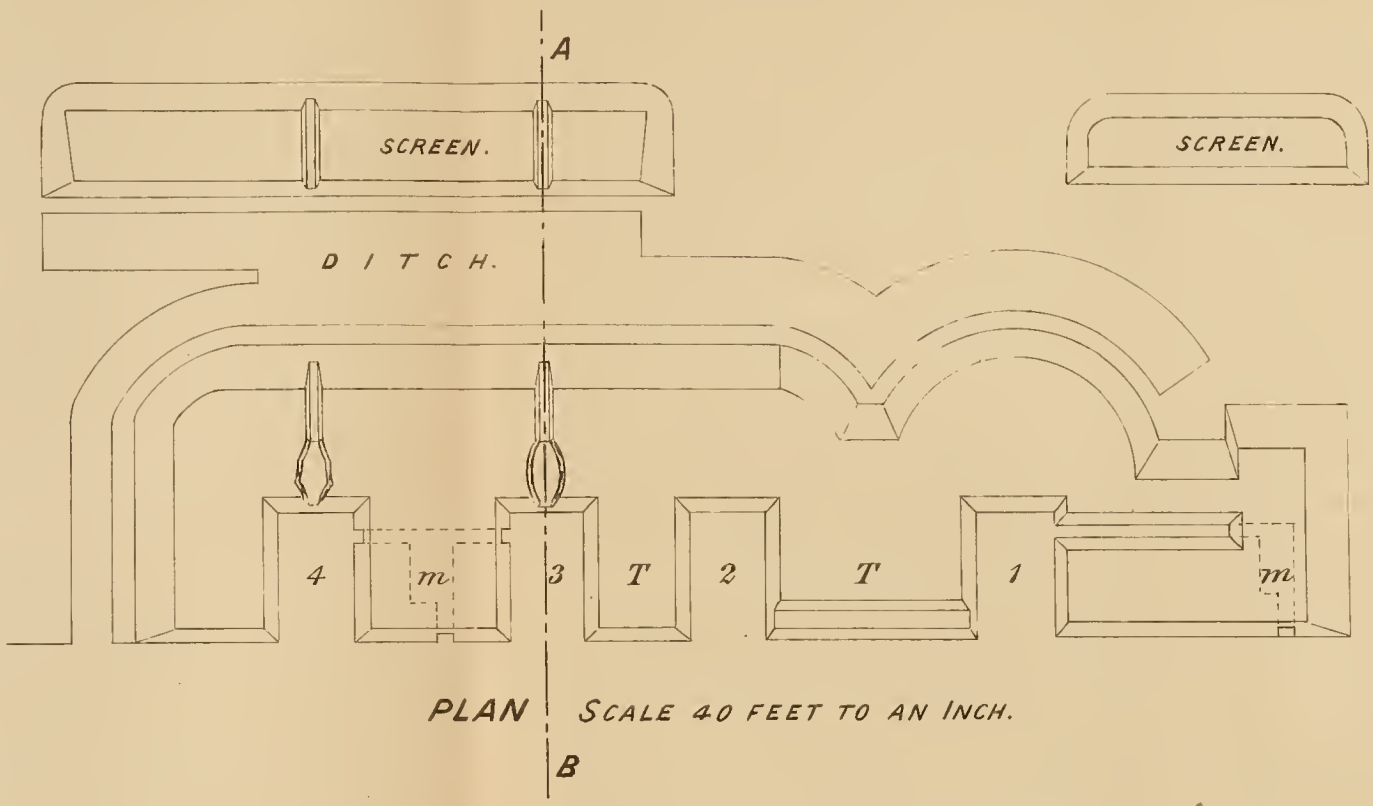
January, 1875.


SKETCH PLAN
OF
SHELL RANGE &c
N
To Pevensey.
Gorse cover.
SHINGLE BEACH.
A
B
C
68 TOWER.
SHELL RANGE.
Temporary railway.
OLD TOLL HOUSE
Branch railway
From Eastbourne
Ballast pit.
63 TOWER.
64 TOWER.
65 TOWER.
TARGET BATTERY.
66 TOWER.
LANGNEY REDOUBT.
67 TOWER
69 TOWER.
(IN RUINS)
BUTT
70 TOWER
(IN RUINS)
BUTT
BUTT
A.B.C. Firing batteries
— — — Shews the limits of
the ground to be kept clear.

PL. II.



TARGET BATTERY.

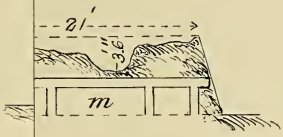


PLAN SCALE 40 FEET TO AN INCH.

1.2.3.4. Nos of Gun portions.
m, m, Magazines.
T. -- Traverses.
E. -- Embrasures.

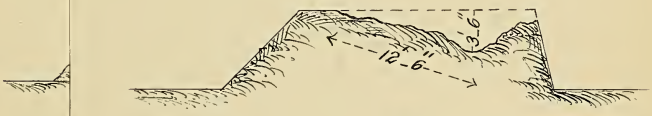
SECTION ON THE LINE A.B.
SCALE 20 FEET TO AN INCH.

(Eastbourne Siege Experiments.)



(Traverse.)

203.



239.

249 TO 268.

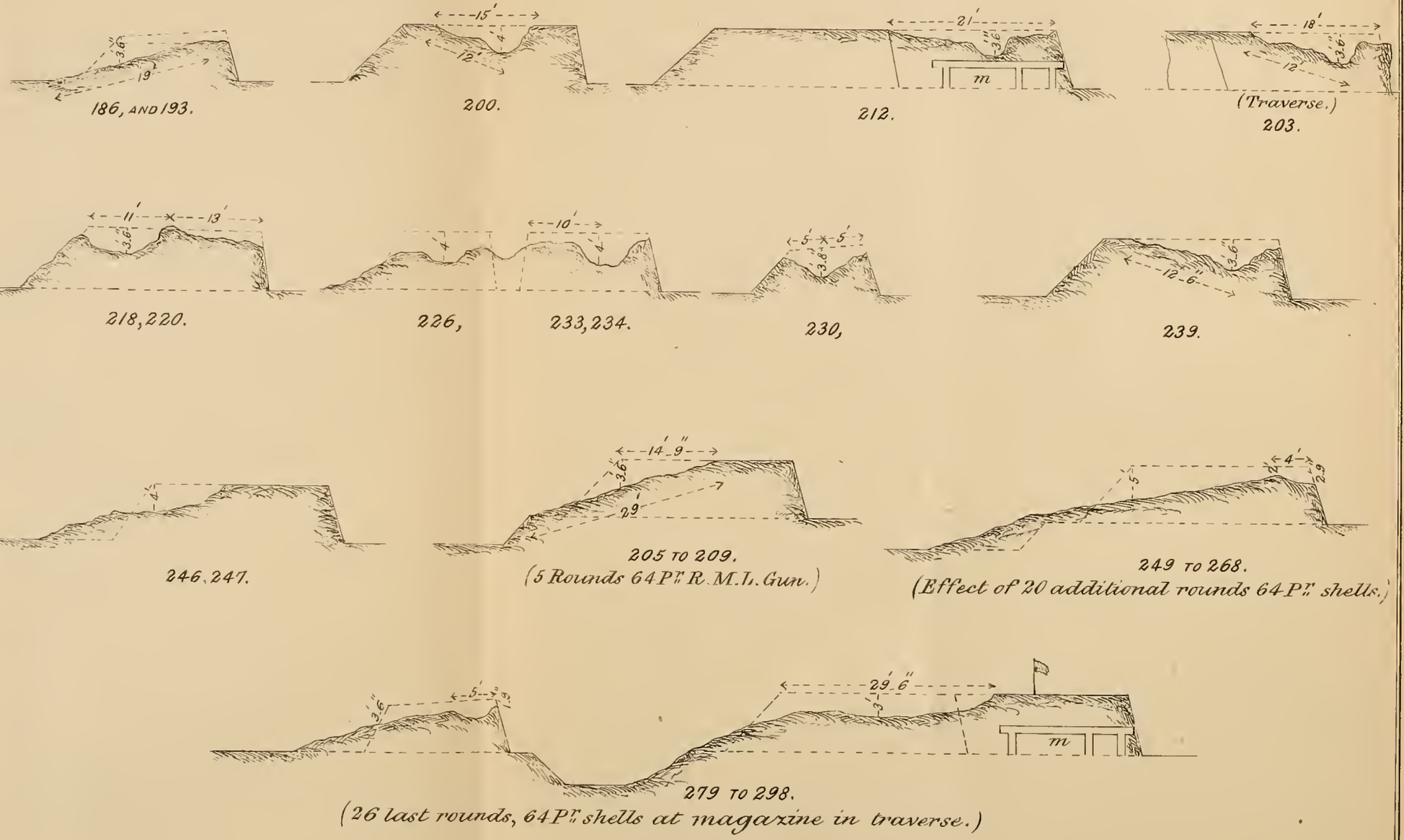
ffect of 20 additional rounds 64 P.F. shells.)

rse.)

rounds causing the craters.

SECTIONS OF SHELL CRATERS.

SCALE 20 FEET TO AN INCH.



N.B. The figures beneath each section denote the Gen.l N.os of the rounds causing the craters.

EXPLANATORY NOTES

ON

BASHFORTH'S "MOTION OF PROJECTILES."

BY

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1. Professor Bashforth's excellent treatise has been written for the purpose of throwing light upon the very complex problem of calculating tha path of a projectile in air. It is not possible to over-estimate the value of this work to the artillery officer, accompanied as it is by tables for practical use. Though it possesses these advantages—and is, moreover, the only text-book upon the subject written in modern times and published in our language—yet there is reason to fear lest its great value should not be recognised by many artillery officers who may find it difficult to follow Mr. Bashforth in some of the subtle reasonings and difficult calculations necessary.

Officers fairly acquainted with the calculus do not always find it an easy task to go through these calculations—which are the record of many difficult obstacles overcome, of original experiments carefully worked out under difficulties, and of theory reduced to practice, by the Professor to whom we British gunners owe a deep debt of gratitude.

The following paper is published in order that Mr. Bashforth's work may be utilised by every artillery officer, even though unacquainted with the differential and integral calculus. That this may be the case the writer has endeavoured—

1stly. To supply steps which Mr. Bashforth has thought it unnecessary always to insert; and also to aid those who are fair mathematicians by stating and explaining difficulties which have occurred to himself while reading the treatise, or which have been pointed out to him by others.

2ndly. To enable those officers who may have forgotten mathematics from want of practice, but who are still acquainted with algebra and can use logarithm tables, to apply the results of Mr. Bashforth's treatise in working out trajectories or in solving other problems in gunnery.

This paper is intended, therefore, for two classes of readers—those who are well acquainted with mathematics, and those who are not; and the writer hopes that he will be excused by the one class for giving detailed explanations of what must be obvious to them, and by the other for inserting proofs and using language which in some cases must appear unintelligible.

The writer trusts that the latter may be enabled to understand the general scope of Professor Bashforth's work; but they must be content to take for granted formulæ proved by the calculus, or by other processes beyond their reach.

Sentences containing proofs of this description will commence with a word *in italics*, in order to save the time of such readers—who should, however, note the results.

At times, the manner in which such a result is arrived at may be made clear by algebraical explanations.

Throughout this paper reference will constantly be made to Professor Bashforth's work, and the equations will retain the numbers given to them there; while, to make it complete, extracts will be occasionally inserted which do not require explanation in themselves.

"Art." refers to articles in the treatise, and the symbol "§" to sections of this paper.

2. Equations of Motion for Determining the Resistance of the Air.

It is carefully explained in Chap. III. how, by means of the Bashforth chronograph, the times of a projectile passing through several screens in succession can be accurately recorded. Thus sufficient data are obtained for determining the resistance of the air, to which the diminution of velocity is principally due. It is, of course, evident that gravity retards during the ascending branch of the curve described by the projectile, and accelerates during the descending branch.

There are two distinct methods of measuring a force:—

(1) Statically, by the weight it will sustain.
(2) Dynamically, by the increase or diminution of velocity it will produce in a given mass "m" during a given time; or—which comes to the same thing—by the momentum it will generate in one second.

These two measures of the same force are connected by the equation

$$P = mf; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (a)$$

where "P" is the statical measure and "f" is the acceleration—*i.e.*, the velocity (feet per second) generated in one second—and consequently "mf" is the momentum generated in one second.

A retarding force, such as the resistance of the air, is a negative acceleration; all the reasonings, therefore, concerning acceleration apply equally to retardation.

If we know the acceleration (or retardation) produced in a given projectile during a known time, and if we find it to be constant for equal times, we can at once find the force which produces it by (a); but in the case before us it is not constant, for it depends upon the velocity. The precise law connecting the resistance of the air with the velocity, has been hitherto, and may be still, considered unknown; for Professor Bashforth has not determined any invariable law, but he has shown that for the average velocities of projectiles it is nearly as the cube of the velocity,* and he has calculated tables for correcting the error in this assumption.

Since, then, the retardation is variable, differential equations of motion must be used, which may be determined from, and are analagous to, the ordinary well-known equations.

The ordinary equations are:—

$$\left.\begin{array}{ll} \text{for uniform velocity} & s = vt,\ \therefore v = \dfrac{s}{t}; \\ \text{for uniform acceleration from rest} & \left\{\begin{array}{l} v = ft,\ \therefore f = \dfrac{v}{t}; \\ s = \dfrac{vt}{2} = \frac{1}{2}ft^2; \\ v^2 = 2fs. \end{array}\right. \end{array}\right\} \ldots\ldots\ldots\ldots\ldots\ldots (b)$$

When the velocity is variable, it may be considered constant for an indefinitely small time, during which an indefinitely small space is described. Hence $v = \dfrac{ds}{dt}$.

When the acceleration is variable, it may be considered constant for an indefinitely small time, during which the increase of velocity is indefinitely small. Hence $f = \dfrac{dv}{dt}$.

$$But\ v = \frac{ds}{dt},\ \therefore f = \frac{d^2s}{dt^2}.$$

$$Also,\ f = v\frac{\frac{dv}{dt}}{v} = v\frac{\frac{dv}{dt}}{\frac{ds}{dt}} = v\frac{dv}{ds}.$$

---

* For low velocities, as the 6th power; for high velocities, as the square.

The differential equations of motion are these :—

$$\left.\begin{aligned} v &= \frac{ds}{dt}, \\ f &= \frac{dv}{dt} \\ &= \frac{d^2s}{dt^2} \\ &= v\frac{dv}{ds} \end{aligned}\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (c)$$

The four equations (c) correspond to the four equations (b), and form the basis of all dynamical problems.

We see them employed in Chap. II. to calculate the well-known equation to the path of a projectile in vacuo.

$$y = x \tan \alpha - \frac{gx^2}{2V^2 \cos^2 \alpha};$$

which is the equation to a parabola. The only force acting on the projectile, in that case, is the vertical force of gravity; therefore, putting
(c). x and y successively for s in "$f = \frac{d^2s}{dt^2}$", we obtain the formulæ employed—viz.,

$$\frac{d^2x}{dt^2} = o, \quad \frac{d^2y}{dt^2} = -g.*$$

Integrating, we obtain $\frac{dx}{dt}$ and $\frac{dy}{dt}$; which are, respectively, the horizontal and vertical velocities at any time. The constants are determined by putting $t = o$, when $\frac{dx}{dt}$ and $\frac{dy}{dt}$ become $V \cos \alpha$ and $V \sin \alpha$ respectively—the horizontal and vertical components of the velocity of projection.

Eliminating "t," the above equation to the parabola is at once obtained.

The process for determining the trajectory when the resistance of the air is considered, is precisely similar.

3. Differencing.

(Chap. III. Arts. 51–53.)

Before considering the experiments on which Mr. Bashforth's calculations are based, it will be necessary to understand thoroughly the processes of differencing and interpolating.

Whenever a function of x (such as x^n, $\log x$, $\sin x$, and other more or less complicated expressions) is calculated for several successive values

* g is negative because gravity pulls in the contrary direction to that in which y is measured.

of x, and does not become infinite for any such or intermediate values, it will be found that the differences between the successive values of the function, and, again, the differences of these differences, &c., alter with a regular increase or decrease. Consequently, if the differences of any § 6. set of observed or incorrectly calculated numbers are found to be irregular, *corrections must be applied to the numbers,* so as to make the differences as regular as possible. (For examples, see Art. 55.)

The effect upon the differences when a number is increased (or diminished) by unity, can be seen in the following scheme. (See Art. 54, and example Art. 53.)

Let N_1, N_2, &c., be the numbers,

Δ_1^1, Δ_2^1, &c., " first differences, so that $\Delta_1^1 = N_2 - N_1$,
$\Delta_2^1 = N_3 - N_2$,

Δ_1^2, Δ_2^2, &c., " second differences, so that $\Delta_1^2 = \Delta_2 - \Delta_1$,

&c., &c.,

and let the differences be supposed (for simplicity) all positive, so that each column increases downwards—*i.e.*, $\Delta_4 > \Delta_3$, $\Delta_7^3 > \Delta_6^3 > \Delta_5^3$, and so on.

	+	+	+	+
N_1				
N_2	Δ_1^1	Δ_1^2		
N_3	Δ_2^1	Δ_2^2	Δ_1^3	
N_4	Δ_3^1	$\Delta_3^2 + 1$	$\Delta_2^3 + 1$	$\Delta_1^4 + 1$
$N_5 + 1$	$\Delta_4^1 + 1$	$\Delta_4^2 - 2$	$\Delta_3^3 - 3$	$\Delta_2^4 - 4$
N_6	$\Delta_5^1 - 1$	$\Delta_5^2 + 1$	$\Delta_4^3 + 3$	$\Delta_3^4 + 6$
N_7	Δ_6^1	Δ_6^2	$\Delta_5^3 - 1$	$\Delta_4^4 - 4$
	&c.,	&c.,	&c.	$\Delta_5^4 + 1$

When N_5 is increased by 1,

Δ_4^1 becomes $N_5 + 1 - N_4 = \Delta_4^1 + 1$,
Δ_5^1 " $N_6 - (N_5 + 1) = \Delta_5^1 - 1$,
Δ_4^2 " $(\Delta_5 - 1) - (\Delta_4 + 1) = \Delta_4^2 - 2$,
&c., &c.

The alterations in each column follow the law of the co-efficients in the binomial theorem.

Thus, if a column of differences requires correcting, owing to its being irregular, it can be seen what alterations must be made in the primary column.

It may be objected that the corrected readings in Art. 55, pp. 41, 42, do not give regular readings, since in the one case the second differences are

57, 57, 58, 58, 57, 58, 58, 57;

and in the other,

24, 24, 25, 25, 25, 24, 24, 25.

Such irregularities are to be met with in all calculations by decimals, owing to the omission of the remaining places of decimals. Had more accuracy been required in either of the cases just mentioned, an additional place of decimals might have been inserted by a further correction of the differences, as follows :—

Bashforth, p. 41.			Further corrected.			
	$+\Delta_1$	$+\Delta_2$		$+\Delta_1$	$+\Delta_2$	$+\Delta_3$
74·889			74·8892			
	2·596			2·5958		
77·485		57	77·4850		572	
	2·653			2·6530		1
80·138		57	80·1380		573	
	2·710			2·7103		2
82·848		58	82·8483		575	
	2·768			2·7678		1
85·616		58	85·6161		576	
	2·826			2·8254		1
88·442		57	88·4415		577	
	2·883			2·8831		2
91·325		58	91·3246		579	
	2·941			2·9410		0
94·266		58	94·2656		579	
	2·999			2·9909		2
97·265		57	97·2645		581	
	3·056			3·0570		
100·321			100·3215			

The actual work of this correction need not be inserted here, as it is to a certain extent laborious, and the principles have been fully explained.

For further explanations concerning differences that are not all positive, see below (§ 5).

4. Prelude to Principles of Interpolation.

(Chap. III., Arts. 54, 55; and Appendix III.)

There is a common process for summing series, an explanation of which may be of use here, since it involves the principle of interpolating.

Let Σ_n be the sum of n layers of a triangular pile of shot; then the first differences are the numbers in the respective layers—namely, 1, 3, 6, 10, 15, &c.

	$+\Delta_1$	$+\Delta_2$	$+\Delta_3$
M$_0$	1		
		2	
M$_1$	3		1
		3	
M$_2$	6		1
		4	
M$_3$	10		1
		5	
M$_4$	15		
M$_5$			

The third difference is found to be constant; then the rule is

$$\Sigma_n = \Sigma_0 + n\Delta_1 + \frac{n \,.\, \overline{n-1}}{1 \,.\, 2}\Delta_2 + \frac{n \,.\, \overline{n-1} \,.\, \overline{n-2}}{1 \,.\, 2 \,.\, 3}\Delta_3$$

$$+ \frac{n \,.\, \overline{n-1} \,.\, \overline{n-2} \,.\, \overline{n-3}}{1 \,.\, 2 \,.\, 3 \,.\, 4}\Delta_4 + \&c.$$

But

$$\Delta_4 \text{ and all further differences} = 0,$$

and

$$\Delta_1 = 1,\ \Delta_2 = 2,\ \Delta_3 = 1;$$

$$\therefore\ \Sigma_n = n + n\,.\,\overline{n-1} + \frac{n\,.\,\overline{n-1}\,.\,\overline{n-2}}{6}$$

$$= n^2 + \frac{n^3}{6} - \frac{n^2}{2} + \frac{n}{3} = \frac{n\,.\,\overline{n+1}\,.\,\overline{n+2}}{1\,.\,2\,.\,3}.$$

Similarly, for a square pile, it will be found that $\Delta_1 = 1$, $\Delta_2 = 3$, $\Delta_3 = 2$, Δ_4, &c., $= 0$, since the third difference is constant.

$$\therefore\ \Sigma_n = n + \frac{3n\,.\,\overline{n-1}}{2} + \frac{n\,.\,\overline{n-1}\,.\,\overline{n-2}}{3}$$

$$= \frac{n\,.\,\overline{n+1}\,.\,\overline{2n+1}}{1\,.\,2\,.\,3},$$

which is the ordinary formula.

This process can be adopted for summing any series whatever, if any column of differences is found to be constant, and consequently all succeeding differences vanish.

Take one more case.

$$\Sigma_n = 1\,.\,3\,.\,5 + 2\,.\,4\,.\,6 + 3\,.\,5\,.\,7 + \&c.$$

$$= 15 + 48 + 105 + 192 + 315 + 480 + \&c. \ldots\ldots\ldots\ldots\ \Delta_1$$

$$33 \quad 57 \quad 87 \quad 123 \quad 165 \ldots\ldots\ldots\ldots\ \Delta_2$$

$$24 \quad 30 \quad 36 \quad 42 \ldots\ldots\ldots\ldots\ \Delta_3$$

$$6 \quad 6 \quad 6 \ldots\ldots\ldots\ldots\ \Delta_4$$

$\therefore\ \Delta_1 = 15,\ \Delta_2 = 33,\ \Delta_3 = 24,\ \Delta_4 = 6,\ \Delta_5$ &c. $= 0$;

$$\therefore\ \Sigma_n = 0 + 15n + \frac{33n\,.\,\overline{n-1}}{2} + \frac{24n\,.\,\overline{n-1}\,.\,\overline{n-2}}{6} + \frac{6n\,.\,\overline{n-1}\,.\,\overline{n-2}\,.\,\overline{n-3}}{24}.$$

This, when reduced, will be of the form

$$An + Bn^2 + Cn^3 + Dn^4,$$

the fourth difference having been constant.

The number of shot in the piles before mentioned was of the form

$$An + Bn^2 + Cn^3,$$

the third difference having been constant in each case.

It may, then, be inferred (or proved by induction) that whenever the rth column of differences is constant, the sum of the series—*i.e.*, the

function of n which we are considering—is a function of the rth order, namely, of the form

$$An + Bn^2 + \ldots\ldots\ldots\ldots + Rn^r.$$

Art. 56. Professor Bashforth found that the second differences of the times occupied by a projectile in passing through successive equal intervals were constant. Hence, putting "s" for any number of intervals (corresponding to "n," any number of terms), and t for the whole time of passing through "s"—*i.e.*, for the sum of the times occupied by each interval (corresponding to Σ_n above)—we have the very important expression

$$t = as + bs^2. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (d)$$

By giving "s" the values 1, 2, 3, &c., successively, the following values are obtained for t:—

$$\begin{array}{lllll} a + b, & 2a + 4b, & 3a + 9b, & 4a + 16b & \\ & a + 3b & a + 5b & a + 7b & \ldots\ldots\ldots\ldots \Delta_1 \\ & & 2b & 2b & \ldots\ldots\ldots\ldots \Delta_2 \end{array}$$

Thus the second difference is constant, which proves the correctness of the formula (d).

Another proof can be given by the calculus as follows:—

Since the second difference of the times is constant, it follows that $\frac{d^2t}{ds^2} = \text{constant} = 2b$, suppose.

Hence, integrating,

$$\frac{dt}{ds} = 2bs + \text{constant}$$
$$= a + 2bs, \text{ suppose};$$

and integrating again,

$$t = as + bs^2 + \text{constant}.$$

But $t = o$ when $s = o$,

$$\therefore\ t = as + bs^2. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (d)$$

Should it not be quite clear that the equation "$\frac{d^2t}{ds^2} = C$" is obtained from the fact that the second difference is constant, the following analysis may serve to throw light upon it:—

If for intervals l the second differences are constant, it will be seen without difficulty that they are also constant for any subdivisions of l.*

---

* *Let* l be subdivided into n equal parts,

Then, referring to the scheme in § 3, we have n differences "δ" corresponding to each Δ^1, which is equal to the sum of such n differences.

Thus from N_2 to N_3 there are n differences, varying from $\frac{\Delta_1{}^1}{n}$ to $\frac{\Delta_2{}^1}{n}$, which differ by $\frac{\Delta_1{}^2}{n}$; therefore, as there are n of them, their differences—*i.e.*, the new second differences—approximate to $\frac{\Delta_1{}^2}{n^2}$, and are, *à fortiori*, constant if the original second differences are constant—*i.e.*, constant to as many places of decimals as appreciably affect the result.

Therefore it follows that the second differences are constant if l is infinitesimal.

Let $l = ds$, and let dt be the consequent increment of the time—*i.e.*, that difference, Δ_1, which corresponds to ds;

$$\therefore \frac{dt}{ds} = \frac{\Delta_1}{l},$$

l being infinitesimal;

$$\therefore \frac{d^2t}{ds^2} = \frac{d\left(\frac{dt}{ds}\right)}{ds} = \frac{d\left(\frac{\Delta_1}{l}\right)}{l} = \frac{d(\Delta_1)}{l^2} = \frac{\Delta_2}{l^2} = \text{constant},$$

since Δ_2 is constant.

5. Principles of Interpolation.

The principle is stated generally as follows:— Art. 54.

$$u_{x+nl} = u_x + n \,.\, \Delta u_x + \frac{n \,.\, \overline{n-1}}{1 \,.\, 2} \,.\, \Delta^2 u_x + \frac{n \,.\, \overline{n-1} \,.\, \overline{n-2}}{1 \,.\, 2 \,.\, 3} \,.\, \Delta^3 u_x + \&c.; \ldots (A)$$

where u_x is a function of x,

u_{x+l} is the value acquired by u_x when x is increased by l,

u_{x+nl} " " " nl;

i.e., first by l, then by l again, and so on.

$$\Delta u_x = u_{x+l} - u_x = \text{first difference},$$

$$\therefore u_{x+l} = u_x + \Delta u_x \ldots\ldots\ldots\ldots (e)$$

Again, putting $x + l$ for x in (e), we have

$$\Delta u_{x+l} = u_{x+2l} - u_{x+l} = \text{the next first difference};$$

$$\therefore u_{x+2l} = u_{x+l} + \Delta u_{x+l}$$

$$= u_x + \Delta u_x + \Delta\,(u_x + \Delta u_x)$$

$$= u_x + 2\Delta u_x + \Delta^2 u_x. \ldots\ldots\ldots\ldots (f)$$

Similarly,

$$u_{x+3l} = u_x + 3\Delta u_x + 3\Delta^2 u_x + \Delta^3 u_x,$$

and generally,

$$u_{x+nl} = u_x + n\Delta u_x + \frac{n \,.\, \overline{n-1}}{1 \,.\, 2} \Delta^2 u_x + \&c.$$

Thus equation (A) is proved, and this is the rule given in § 4 for summing series.

In proving (f) the process is not one of multiplying out, when we say that $\Delta(u_x + \Delta u_x) = \Delta u_x + \Delta^2 u_x$; but it is this—namely, the difference of $(u_x + \Delta u_x)$ is the difference of u_x + the difference of Δu_x, which latter is (by definition) the second difference of u_x.

$$\therefore\ \Delta(u_x + \Delta u_x) = \Delta u_x + \Delta^2 u_x.$$

Much depends upon equation (A); so that even those who are not acquainted with the calculus should endeavour to understand it.

This equation being a general equation, it may excite surprise that the letter "l," to which various values may be given, occurs on one side only of the equation. Any difficulty on this account is easily explained away by the consideration that the magnitude of Δu_x, &c., depends upon the magnitude of "l," the increment of x; therefore "l" is involved in Δu_x, &c.

Equation (A) may be supposed to be represented by a continuous curve, such that, for any value of "n"—the abscissa—the corresponding ordinate should represent the value of "u_{x+nl};" Δu_x, &c., being treated as constants, since they are independent of the value of "n." From this it can be seen that, although "n" is essentially an integer in the proof of equation (A), yet the error will be infinitesimal if it is considered to hold for all intermediate values of "n." It does hold for "$n = o$"; hence it may be used for all fractional as well as integral values of "n."

It is used with fractional values for interpolating. (See Appendix III., where it is numbered (I.), and transformed into other, at times, more convenient forms (II.), (III.), (IV.), which the reader need not trouble himself to get up, unless he is studying the subject of "finite differences," since they are not essential to the due comprehension of Mr. Bashforth's work).

Equation (A), then, is the formula for interpolation; for if we know u_x, u_{x+l}, u_{x+2l}, &c., we can, by giving fractional values to "n," obtain the values of functions intermediate to u_x and u_{x+l}.

Examples from logarithm tables will be given on the application of equation (A) to interpolation, after considering what algebraical signs must be prefixed to the differences in all cases.

§ 3. In the preceding investigations all the differences have been supposed

positive—*i.e.*, the original function and all the successive differences have been supposed to increase when "x" (the independent variable) increases; but this will seldom be found to be the case.

The differences are all positive in the case of the series in § 4, but not in the example from logarithms given in Art. 53. (See also § 6.)

All the preceding results are, however, equally true when any of the differences are negative, provided the proper signs are affixed.

To avoid error, it must be remembered that negative quantities are increased when made numerically less, and diminished when made numerically greater; that is,

$$-4 > -5 \qquad \because -4 = -5 + 1$$

$$-4 < -3 \qquad \because -4 = -3 - 1$$

Hence, in any column of positive differences (see scheme Art. 54, or § 3), if they are found to diminish as they proceed—*i.e.*, as x increases —the next column will consist of negative differences. If these, again, are found to diminish numerically as they proceed, they are really increasing; therefore, the differences in the next column are positive and not negative. Of course, also, if negative differences are increasing numerically, the next column is positive. This should be carefully thought over, as it is necessary in order to obtain a clear comprehension of the nature of differences.

Suppose that, in the scheme § 3, the numbers "N" in the first column are increasing, then the first differences "Δ" are positive; for $\Delta_1 = N_2 - N_1$, which is positive, since $N_2 > N_1$.

Suppose that the first differences are also increasing,

$$\therefore \Delta_2 > \Delta_1. \quad \therefore \Delta_1^2 = \Delta_2 - \Delta_1 \text{ is positive;}$$

that is, the second differences are positive. Suppose these to be diminishing,

$$\therefore \Delta_2^2 < \Delta_1^2. \quad \therefore \Delta_1^3 = \Delta_2^2 - \Delta_1^2 \text{ is negative;}$$

that is, the third differences are negative. Suppose, again, that these also are diminishing,

$$\therefore \Delta_2^3 < \Delta_1^3. \quad \therefore \Delta_1^4 = (-\Delta_2^3) - (-\Delta_1^3)$$
$$= \Delta_1^3 - \Delta_2^3 \text{ is not negative but } \textit{positive}.$$

If these, again, are diminishing, Δ^5 will be negative.

We see, then, that if all the columns of differences are diminishing, they will be alternately negative and positive; whereas, if all are increasing, all will be positive.

It must be remarked with regard to the corrections to be applied in differencing, that if any column is negative, those quantities must be numerically subtracted which would have had to be added if it had been positive; and *vice versâ*. § 3.

6. Examples on Interpolation.

$$u_{x+nl} = u_x + n\Delta u_x + \frac{n\,.\,\overline{n-1}}{1\,.\,2}\Delta^2 u_x + \frac{n\,.\,\overline{n-1}\,.\,\overline{n-2}}{1\,.\,2\,.\,3}\Delta^3 u_x + \&c. \ldots\ldots(A)$$

Find log 142; given log 15, 16, 17, &c.

		$+\Delta$	$-\Delta^2$	$+\Delta^3$	$-\Delta^4$	$+\Delta^5$	$-\Delta^6$
Let $u_x =$ log 140 =	2·1461280						
		299633					
$\therefore u_{x+l} =$ log 150 =	2·1760913		19346				
		280287		2348			
$u_{x+2l} =$ log 160 =	2·2041200		16998		403		
		263289		1945		86	
$u_{x+3l} =$ log 170 =	2·2304489		15053		317		19
		248236		1628		67	
$u_{x+4l} =$ log 180 =	2·2552725		13425		250		
		234811		1378			
$u_{x+5l} =$ log 190 =	2·2787536		12047				
		222764					
$u_{x+6l} =$ log 200 =	2·3010300						

Here, $x = 140$, $l = 10$. The columns of differences being all diminishing are alternately positive and negative, as explained above.

To find log 142, we must put $n = \frac{1}{5}$ in (A).

See eqⁿ (c_1) App. III. $\therefore$ log 142 $= \log 140 + \frac{1}{5} \times \cdot 0299633 - \dfrac{\frac{1}{5} \times \frac{-4}{5}}{2}\Delta^2 + \dfrac{\frac{1}{5} \times \frac{-4}{5} \times \frac{-9}{5}}{6}\Delta^3 - \&c.$

$$= \log 140 + \tfrac{1}{5}\Delta + \tfrac{2}{25}\Delta^2 + \tfrac{6}{125}\Delta^3 + \tfrac{21}{625}\Delta^4 + \tfrac{399}{15625}\Delta^5 + \tfrac{1596}{78125}\Delta^6 + \&c.$$

log 140 =			= 2·1461280
$\frac{1}{5}\Delta =$			= ·00599266
$\frac{2}{25}\Delta^2 =$	$\frac{8}{100}$	× ·0019346	= ·00015477
$\frac{6}{125}\Delta^3 =$	$\frac{48}{1000}$	× ·0002348	= ·00001128
$\frac{21}{625}\Delta^4 =$	$\frac{336}{10000}$	× ·0000403	= ·00000135
$\frac{399}{15625}\Delta^5 =$			= ·00000022
			$\therefore$ log 142 = 2·1522883

In like manner, putting $n = \frac{2}{5}$, we obtain

See eqⁿ (c_2) App. III. $$\log 144 = \log 140 + \tfrac{2}{5}\Delta + \tfrac{3}{25}\Delta^2 + \tfrac{8}{125}\Delta^3 + \tfrac{26}{625}\Delta^4 + \&c.$$

So also, putting $n = \frac{3}{5}$ and $\frac{4}{5}$ successively, we obtain log 146 and log 148.

Thus we have a complete interpolation.

Eqⁿ (a) App. III. Log 141 may either be found by putting $n = \frac{1}{10}$, or by making use of the results already obtained, taking fresh differences and putting $n = \frac{1}{2}$.

Art. 55. Before studying the practical use made of interpolation by Mr. Bashforth, we must consider the main principles of his chronograph.

ERRATA.

Page 169, line 19, "the next column is positive;" *for* "positive," *read* "negative."

" 170, line 3, *read* "log 14, 15, 16, 17, &c."

ERRATA.

Page 198, Note ‡, "stated" should be "statical."

Page 204, Note *, p. 4. should be 195.

Page 204, Note †, Note I., p. 15. should be 206.

Page 206, Note *, "Williams" should be "Willans,"

Page 210, Note †, p. 16. should be 207.

7. The Bashforth Chronograph.*

(Chap. III. to Art. 52.)

The chronoscopes in existence were unable to register the passage of a projectile through more than two screens. They therefore determined the time of flight through one interval only; and manifest errors would have been involved had several such instruments been used for Mr. Bashforth's purpose—viz., to measure the times occupied by the same projectile in passing through successive intervals. He was therefore led to the invention of the chronograph which bears his name, for the purpose of attaining this object with a single circuit. The screens were so constructed that the projectile passing through any one would not only interrupt, but instantly restore the circuit; and the fact of its doing so was recorded in a spiral, by a slowly descending electro-magnet and pricker, on a drum which was made to revolve as uniformly as possible by being attached to a fly-wheel. The drum being annexed to a graduated disc, the distances of the records from a fixed zero could be read off.

The next difficulty was to convert these distances into time, since the rate of revolution of the drum could not be made perfectly uniform.

To accomplish this, a clock beating half-seconds was constructed, so that at each second the pendulum broke and made contact in another circuit, also provided with an electro-magnet and pricker, which thus marked each second on the same drum.

By comparing these two separate records, the exact times occupied by the projectile in passing each screen could be read off, as explained in the next section.

The above is merely a brief outline of the method adopted, and omits all the interesting details—such as the construction of the screens, and the very ingenious way in which the difficulties connected with remaining magnetism were got over. A complete description is given in Arts. 46–50.

Before comparing the screen and clock readings, they required to be corrected by differencing. Art. 51.

The results obtained (as explained below) favoured the adoption of the formula

$$\text{resistance} = 2bv^3; \qquad \text{Art. 52.}$$

where $2b$ is not quite constant.

Also, for different projectiles of the same class, the resistance was found to vary as $\frac{d^2}{w}$; where $d =$ diameter and $w =$ weight of projectile.

Also, the resistance of the air evidently varies as the pressure, which varies as the density. Hence, any result that is obtained for the resistance must be corrected for density by dividing by the number expressing it in terms of the unit of density: in fact, it is a simple proportion.

* For full description see "Proceedings, R.A. Institution," Vol. V. p. 161, August, 1866.

Let 1 be the density, for barometer 30°, thermometer 60°,
δ " " at the time of the experiment,
R " resistance found,
R' " corrected resistance.

$$1 : \delta :: R' : R;$$
$$\therefore\ R' = \frac{R}{\delta}.$$

8. Resistance expressed in Terms of the Differences of the Times.

(Article 54.)

This article begins by proving equation (A), and then finds another value for "u_{x+nl}" by Taylor's theorem, which must be taken for granted by those who have not read the calculus. They should, however, study the article, or, at any rate, the concluding paragraph of it, as it forms the connecting link between Mr. Bashforth's experiments and theories.

The symbol $\frac{du_x}{dx}$ means the limit of $\frac{\Delta u_x}{l}$ when l is diminished,

and " $\frac{d^2u_x}{dx^2}$ " " $\frac{\Delta^2 u_x}{l^2}$ " "

§ 5. $$u_{x+nl} = u_x + n\Delta u_x + \frac{n\,.\,\overline{n-1}}{1\,.\,2}\Delta^2 u_x + \frac{n\,.\,\overline{n-1}\,.\,\overline{n-2}}{1\,.\,2\,.\,3}\Delta^3 u_x \ldots\ldots\ldots (A)$$

Also by Taylor's theorem,

$$u_{x+nl} = u_x + \frac{du_x}{dx}\,.\,nl + \frac{d^2u_x}{dx^2}\cdot\frac{n^2l^2}{1.2} + \frac{d^3u_x}{dx^3}\cdot\frac{n^3l^3}{1.2.3} + \&c. \ldots\ldots\ldots (B)$$

Equate co-efficients of "n" in these identities.

$$\therefore\ l\frac{du_x}{dx} = \Delta u_x - \tfrac{1}{2}\Delta^2 u_x + \tfrac{1}{3}\Delta^3 u_x - \&c., \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (g)$$

$$l^2\frac{d^2u_x}{dx^2} = \Delta^2 u_x - \Delta^3 u_x + \tfrac{11}{12}\Delta^4 u_x - \tfrac{10}{12}\Delta^5 u_x + \tfrac{137}{180}\Delta^6 u_x - \&c. \ldots\ldots\ldots (h)$$

§ 5. This is made more convergent by putting "$x - l$" for "x" in (e).

$$\Delta u_{x-l} = u_x - u_{x-l},$$
$$\therefore\ u_x = u_{x-l} + \Delta u_{x-l},$$
$$\therefore\ \Delta^2 u_x = \Delta^2 u_{x-l} + \Delta^3 u_{x-l}, \&c., \&c.,$$
$$\therefore\ l^2\frac{d^2u_x}{dx} = \Delta^2 u_{x-l} - \tfrac{1}{12}\Delta^4 u_{x-l} + \tfrac{1}{12}\Delta^5 u_{x-l} - \tfrac{13}{180}\Delta^6 u_{x-l} + \&c., \ldots\ldots (h')$$

by simple substitution.

Again, it is made still more convergent; for equation (e) gives

$$u_x = u_{x-l} + \Delta u_{x-l}. \qquad \S\ 5.$$

$$\therefore\ -\tfrac{1}{12}\Delta^4 u_{x-l} = -\tfrac{1}{12}\Delta^4 u_{x-2l} - \tfrac{1}{12}\Delta^5 u_{x-2l}$$

$$\tfrac{1}{12}\Delta^5 u_{x-l} = \tfrac{1}{12}\Delta^5 u_{x-2l} + \tfrac{1}{12}\Delta^6 u_{x-2l}$$

$$-\tfrac{13}{180}\Delta^6 u_{x-l} = -\tfrac{13}{180}\Delta^6 u_{x-2l} - \tfrac{13}{180}\Delta^7 u_{x-2l}$$

$\therefore$ by addition, and putting $u_{x-2l} = u_{x-3l} + \Delta u_{x-3l}$, &c., &c.,

$$l^2 \frac{d^2 u_x}{dx} = \Delta^2 u_{x-l} - \tfrac{1}{12}\Delta^4 u_{x-2l} + \tfrac{1}{90}\Delta^6 u_{x-3l} - \tfrac{1}{560}\Delta^8 u_{x-4l} + \text{\&c.} \ \ldots\ldots(h'')$$

In order to apply these formulæ (g) and (h''),

Let "x" be the distance to any screen, and be denoted by "s,"

Let "l" be the distance between any two screens,

Let u_s be the time that the projectile takes in passing through the space "s," and be denoted t_s.

Then Δu_s, Δu_{s+l}, &c., are the times occupied in passing through the successive intervals, and Δu_{s-l} is the time for the preceding interval, and so on.

$\Delta^2 u_s$, &c., are the differences of these times.

$\dfrac{du_s}{ds} = \dfrac{dt_s}{ds} = \dfrac{1}{v_s}$, where v_s is the velocity at the screen in question. (c), § 2.

$\dfrac{d^2 u_s}{ds^2} = \dfrac{d^2 t_s}{ds^2} = -\dfrac{d^2 s}{dt_s^2} \cdot \left(\dfrac{dt_s}{ds}\right)^3$* $= -\dfrac{f_s}{v_s^3}$ from equations (c), where f_s is § 2. the retardation (because negative) at the same screen. Hence we obtain from (g) and (h''), by writing s for x and t for u, and making these substitutions,

$$\frac{l}{v_s} = \Delta t_s - \tfrac{1}{2}\Delta^2 t_s + \tfrac{1}{3}\Delta^3 t_s - \tfrac{1}{4}\Delta^4 t_s + \text{\&c.}$$

$$-\frac{l^2 f_s}{v_s^3} = \Delta^2 t_{s-l} - \tfrac{1}{12}\Delta^4 t_{s-2l} + \tfrac{1}{90}\Delta^6 t_{s-3l} - \text{\&c.}$$

$$\therefore\ v_s = \frac{l}{\Delta t_s - \tfrac{1}{2}\Delta^2 t_s + \tfrac{1}{3}\Delta^3 t_s - \tfrac{1}{4}\Delta^4 t_s + \text{\&c.}}, \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$f_s = -\frac{v_s^3}{l^2}\left(\Delta^2 t_{s-l} - \tfrac{1}{12}\Delta^4 t_{s-2l} + \dagger\tfrac{1}{90}\Delta^6 t_{s-3l} - \text{\&c.}\right) \ \ldots\ldots\ldots\ldots\ldots(2)$$

Thus we have both the velocity and the retardation at any screen § 7.

---

* $\dfrac{dt}{ds} = \dfrac{1}{\frac{ds}{dt}} = y$, suppose,

$$\frac{d^2 t}{ds^2} = \frac{dy}{ds} = \frac{dy}{dt} \cdot \frac{dt}{ds};\ \text{but}\ \frac{dy}{dt} = -\frac{\frac{d^2 s}{dt^2}}{\left(\frac{ds}{dt}\right)^2},$$

$$\therefore\ \frac{d^2 t}{ds^2} = -\frac{d^2 s}{dt^2} \cdot \left(\frac{dt}{ds}\right)^3.$$

† Misprint here in Bashforth—viz., $\frac{13}{90}$.

expressed in terms of the differences of the times, which, it has been shown, can be ascertained by means of Mr. Bashforth's chronograph and screens.

9. Application to Practical Examples.

(Article 55).

Mr. Bashforth describes how—

1st. The screens were placed 150 ft. apart. $\therefore l = 150$.

2nd. The readings of the clock were taken for five consecutive seconds, during which time the gun was fired.

3rd. These readings were corrected by differencing,

4th. They were interpolated for half-seconds.

5th. " " tenths of seconds, when the differences appeared nearly constant; so that for smaller fractions of seconds simple proportion could be used in place of further interpolation.

6th. The gun was fired about the third second, and the readings were taken for the time of the projectile passing through each screen.

7th. These readings were corrected by differencing.

8th. They were compared with the former interpolated readings; thus the time of each screen being passed was very accurately obtained, viz.—

Screen.	Time in secs.	Δt	$\Delta^2 t$
1	3·0526		
		1090	
2	3·1616		24
		1114	
3	3·2730		24
		1138	
4	3·3868		25
		1163	
5	3·5031		25
		1188	
6	3·6219		25 $= \Delta^2 t_5$
		1213	
7	3·7432		24
		1237*	
8	3·8669		24
		1261	
9	3·9930		25
		1286	
10	4·1216		

Suppose the velocity and retardation to be required at the fifth screen —namely, v_5 and f_5.

Here $\Delta t_5 = \cdot 1188$; $\Delta^2 t_5 = \cdot 0025$; $\Delta^3 t_5$, &c., vanish in the first four places of decimals.

Also $\Delta^2 t_4 = \cdot 0025$; which is required for substitution in (2), since "$s - l$" brings us to the fourth screen.

$$\therefore\ v_5 = \frac{150}{\Delta t_5 - \frac{1}{2}\Delta^2 t_5 + \&c.} = \frac{150}{1188 - \cdot 00125} = \frac{150}{\cdot 11755} = 1276\cdot 1 \text{ f.s.}$$ Eq^{n} (1), § 8.

$$\text{Also } f_5 = -\frac{v_5^3}{150|^2}(\Delta^2 t_4 - \tfrac{1}{12}\Delta^4 t_3 + \&c.)^*$$ Eq^{n} (2), § 8.

$$= -v_5^3 \cdot \frac{\cdot 0025}{150^2} = -2bv_5^3, \text{ suppose, } = -(1000)^3 \times 2b \times \left(\frac{v_5}{1000}\right)^3.$$

If we were to calculate f at the other screens we should get different results, because $\Delta^2 t$ is not absolutely constant; but after making many similar experiments we should find that the value of "$2b$" depends on the velocity but is very nearly constant (as has been before remarked) for velocities near 1200 f.s.

Tables, then, are required to give $2b$ for all reasonable velocities; but this is so small a quantity (for $\frac{\cdot 0025}{150|^2} = \cdot 0000001$), that it is more convenient to use $(1000)^3 \times 2b$.

Again, in the course of experiments with different calibres of the same class (*i.e.*, spherical or ogival-headed projectiles), it was found that

$$(1000)^3 \times 2b \text{ varied as } \frac{d^2}{w} = K\frac{d^2}{w}, \text{ suppose.}$$

In order to make one table serve for all calibres, it is manifestly convenient to tabulate values of $K = 2b\ (1000)^3 \cdot \frac{w}{d^2}$, instead of $2b\ (1000)^3$, which would only serve for one calibre. Table (I.)

Of course K is affected by the above-mentioned fluctuations in the value of $2b$.

In the experiment which forms the subject of this article $d = 4\cdot 92$ ins., $w = 23\cdot 84$ lbs., Art. 55.

$$\therefore\ K = \frac{\cdot 0025}{(150)^2}(1000)^3 \cdot \frac{23\cdot 84}{(4\cdot 92)^2} = 109\cdot 4.$$

But the density of the air was 1·0076, § 7.

$$\therefore \text{ reduced value of } K = \frac{109\cdot 4}{1\cdot 0076} = 108\cdot 6.$$

This, then, is the number to be tabulated as the value of K, corresponding to a velocity of 1276·1 f.s.; but this has been derived from one experiment only. The values of K in Table (I.) have been computed from a vast number of experiments undertaken by Mr. Bashforth, aided by the officers he mentions. The value, then, that we have just obtained naturally does not tally exactly with what we find in the table, viz.—

vel.	k.
1270	108·5
1280	108·3

* Misprints in Bashforth:—1337 should be 1237; $(\Delta^2 t_2 - \frac{1}{12}\Delta^4 t_4)$ should be $(\Delta^2 t_4 - \frac{1}{12}\Delta^4 t_3)$.

It will be found, in using the tables, that errors up to 5 in the values of K are of very slight consequence.

10. ($f = -2bv^3$) PROVED FROM ($\Delta^2 t = constant$).

(Article 56).

§ 9. *It has* been shown by experiment that $\Delta^2 t$ is very nearly constant for equal alterations in the value of s,

§ 4. $$\therefore\ t = as + bs^2;$$

"a" and "b" being unknown constants.

$$\therefore\ \frac{dt}{ds} = a + 2bs,$$

Eq^{ns} (c), § 2. $$\therefore\ \frac{ds}{dt} = v = \frac{1}{a + 2bs},$$

$$\therefore\ \frac{d^2s}{dt^2} = f = -\frac{2b\dfrac{ds}{dt}}{(a + 2bs)^2} = -2bv^3.$$

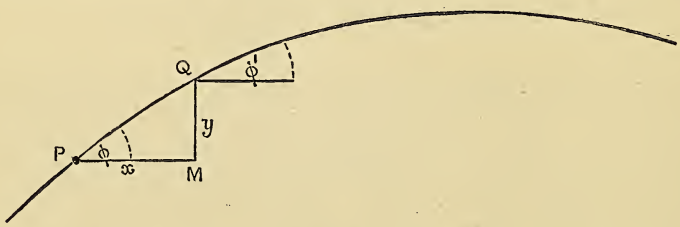
N.B.—There is an erratum in Art. 57. Instead of $f_3 = -\frac{v_3^3}{l_3^3}(\Delta^2 t_2 - \Delta^3 t_2)$ it shoud be $f_3 = -\frac{v_3^3}{l_2}(\Delta^2 t_3 - \Delta^3 t_3)$ from the first of the formulæ (h) in § 8. This is used because $\Delta^3 t$ has a value, but $\Delta^4 t$ has not one; consequently, in the next line, read ·00326 for ·00316. This alteration runs on.

11. Motion of a Projectile in a Resisting Medium.

(Chapter IV.)

Bernoulli's method of calculating the motion of a projectile is merely historical, and is not necessary to what follows.

Arts. 60, 61. Professor Bashforth's method is the following:—



Let ϕ, ϕ' be the inclinations of the trajectory at any two points, P, Q, on the same side of the vertex.

Let v_ϕ and $v_{\phi'}$ denote the velocities at these points; u_ϕ and $u_{\phi'}$ denote the horizontal components of these velocities.

$$PM = x,\ QM = y,\ \text{time of flight from } P \text{ to } Q = t.$$

Formulæ are calculated which express x, y, t in terms of ϕ, ϕ' and the velocity "u_0" that would be attained at the vertex if K (*i.e.*, $2b$) were constant at the mean value adopted for the portion PQ.

Another formula gives u_0 in terms of u_ϕ, and again $u_{\phi'}$ in terms of u_0.

Thus, starting from the beginning of the trajectory, where ϕ and u_ϕ are known, we can determine the position of the point where the inclination is ϕ'; then treating this as a fresh starting-point, we can determine another point in like manner up to the vertex, where $\phi = 0$.

The descending branch is similarly calculated from the vertex as a first starting-point.

The horizontal components only of the velocities enter into these calculations, but the true velocity at any point can always be found; for

$$v_\phi = u_\phi \,.\, \sec \phi.$$

The proof of the formulæ requires the calculus, so those who have not learnt it must take the results for granted—viz., equations (2), (6), (7), (8).

Some steps will be omitted in the following, as the whole is given in Arts. 61, 62.

The following elementary formulæ must be borne in mind:—

$\frac{ds}{dt} = v$, and $\frac{d^2s}{dt^2} = f$ are the velocity and acceleration in direction of tangent, Eq^{ns} (*e*), § 2.

$\frac{dx}{dt} = u$, and $\frac{d^2x}{dt^2}$ " horizontal components of do. do.

$\frac{dy}{dt}$ and $\frac{d^2y}{dt^2}$ " vertical " "

In this case $f = -2bv^3$. § 9, 10.

* Let $p = \frac{dy}{dx} = \tan\phi$, $\frac{dx}{ds} = \cos\phi$, $\frac{dy}{ds} = \sin\phi$,

$$\overline{\frac{ds}{dx}}\Big|^2 = 1 + \overline{\frac{dy}{dx}}\Big|^2 = 1 + p^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)$$

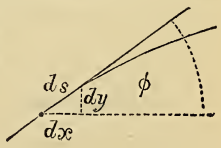
$$\text{Since } p = \frac{dy}{dx} = \frac{\frac{dy}{dt}}{\frac{dx}{dt}}, \quad \therefore \frac{dp}{dt} = \frac{\frac{dx}{dt}\cdot\frac{d^2y}{dt^2} - \frac{dy}{dt}\cdot\frac{d^2x}{dt^2}}{\overline{\frac{dx}{dt}}\Big|^2} \ldots\ldots\ldots\ldots (j)$$

The first step in this, and similar dynamical problems, is to state the § 2.

---

* This is evident with a figure. "ds," being an infinitesimal portion of arc, may be treated as a straight line coinciding with the tangent.

$$\overline{ds}|^2 = \overline{dx}|^2 + \overline{dy}|^2, \therefore \overline{\frac{ds}{dx}}\Big|^2 = 1 + \overline{\frac{dy}{dx}}\Big|^2.$$



"equations of motion" correctly, as in the former case of a projectile in vacuo.

They are—

horizontal acceleration $\frac{d^2x}{dt^2} = f \cos \phi = f \frac{dx}{ds} = f \frac{dx}{dt} \cdot \frac{dt}{ds}$, ...(*k*)

vertical " $\frac{d^2y}{dt^2} = f \sin \phi - g = f \frac{dy}{ds} - g = f \frac{dy}{dt} \cdot \frac{dt}{ds} - g$.....(*l*)

A simpler form can be obtained before substituting the value of f.

Multiply (*k*) by $\frac{dy}{dt}$ and (*l*) by $\frac{dx}{dt}$, and subtract.

$$\therefore \frac{d^2y}{dt^2} \cdot \frac{dx}{dt} - \frac{d^2x}{dt^2} \cdot \frac{dy}{dt} = -g \frac{dx}{dt};$$

Eq^n (*j*). $$\therefore \frac{dp}{dt} \cdot \frac{dx}{dt} = -g. \quad \text{.....(1)}$$

(*k*) becomes $$\frac{d^2x}{dt^2} = -2b \overline{\frac{ds}{dt}}^3 \cdot \frac{dx}{ds} = -2b \overline{\frac{ds}{dx}}^2 \cdot \overline{\frac{dx}{dt}}^3$$

Eq^n (*i*). $$= -2b\,(1 + p^2) \cdot \overline{\frac{dx}{dt}}^3.$$

In order to integrate this, bring $\overline{\frac{dx}{dt}}^3$ over to the left and multiply by

Eq^n (1). $\frac{1}{\frac{dx}{dt}} = -\frac{1}{g} \frac{dp}{dt}$.

$$\therefore \frac{\frac{d^2x}{dt^2}}{\overline{\frac{dx}{dt}}^4} = \frac{2b}{g}(1 + p^2) \frac{dp}{dt},$$

$$\therefore -\tfrac{1}{3} \cdot \frac{1}{\overline{\frac{dx}{dt}}^3} = -\tfrac{1}{3} \cdot \frac{1}{u_0^3} + \frac{2b}{g}\left(p + \frac{p^3}{3}\right),$$

by integrating, the constant being determined by putting $\phi = 0$ (at the vertex), so that $p = 0$; $\frac{dx}{dt} = u_0$.

$$\therefore \frac{1}{u^3} = \frac{1}{u_0^3} - \frac{2b}{g}(3p + p^3). \quad \text{.....(2)}$$

Hence, putting for $\frac{1}{u}$ its value from (1), viz. $-\frac{1}{g} \cdot \frac{dp}{dt}$,

$$\frac{dp}{dt} = -\frac{g}{u_0}\left\{1 - \frac{2bu_0^3}{g}(3p + p^3)\right\}^{\frac{1}{3}}.$$

But $\frac{2bu_0^3}{g} = \frac{Mf_0}{Mg}$, where $\begin{cases} f_0 = \text{retardation at vertex,*} \\ M = \text{mass of projectile,} \end{cases}$

§ 2. $$= \frac{\text{resistance at vertex}}{\text{weight of projectile}} = \gamma,^* \text{ suppose.} \quad \text{.....(m)}$$

$$\therefore (\textit{integrating}) \quad t = -\frac{u_0}{g} \int^{p}_{p'} \frac{dp}{\{1 - \gamma(3p + p^3)\}^{\frac{1}{3}}}; \quad \text{.....(3)}$$

---

* Compare definition of u_0, above.

where p and p' are the limits of integration; that is, this expression, if integrable, would give the time occupied in passing from an inclination ϕ to ϕ'—*i.e.*, from P to Q. Eq^n (*i*).

Evidently the time to Q is greater than that to P; that is, the time increases as $\tan\phi$ or p diminishes. This explains the negative sign.

Again, $$-g = \frac{dp}{dt}\cdot\frac{dx}{dt} = \frac{dp}{dx}\cdot\overline{\frac{dx}{dt}}\Big|^2,$$ Eq^n (1).

$$\therefore \frac{dx}{dp} = -\frac{1}{g}\,.\,u^2 = -\frac{u_0^2}{g}\{1-\gamma(3p+p^3)\}^{-\frac{2}{3}};$$

$$\therefore x = -\frac{u_0^2}{g}\int^{p}_{p'}\frac{dp}{\{1-\gamma(3p+p^3)\}^{\frac{2}{3}}}. \quad \text{.....(4)}$$

Again, $$\frac{dy}{dp} = \frac{dy}{dx}\cdot\frac{dx}{dp} = p\frac{dx}{dp};$$

$$* \therefore y = -\frac{u_0^2}{g}\int^{p}_{p'}\frac{p\,dp}{\{1-\gamma(3p+p^3)\}^{\frac{2}{3}}}. \quad \text{.....(5)}$$

Equations (3), (4), (5), may be put differently.

$$p = \tan\phi,\ \therefore dp = \sec^2\phi\,d\phi = (1+p^2)\,d\phi;$$

$$\therefore t = -\frac{u_0}{g}\int^{\phi}_{\phi'}\frac{(1+p^2)\,d\phi}{\{1-\gamma(3p+p^3)\}^{\frac{1}{3}}} = -\frac{u_0}{g}\,({}^{\phi}T_{\gamma}{}^{\phi'}) \text{ suppose, ...(6)}$$

$$* \therefore x = -\frac{u_0^2}{g}\int^{\phi}_{\phi'}\frac{(1+p^2)\,d\phi}{\{1-\gamma(3p+p^3)\}^{\frac{2}{3}}} = -\frac{u_0^2}{g}\,({}^{\phi}X_{\gamma}{}^{\phi'}) \quad \text{" ...(7)}$$

$$\therefore y = -\frac{u_0^2}{g}\int^{\phi}_{\phi'}\frac{(p+p^3)\,d\phi}{\{1-\gamma(3p+p^3)\}^{\frac{2}{3}}} = -\frac{u_0^2}{g}\,({}^{\phi}Y_{\gamma}{}^{\phi}) \quad \text{" ...(8)}$$

A few words of explanation are here needed concerning the results obtained and the symbols used.

"$2b$" is a variable, $\therefore$ "γ" is a variable, independent of ϕ; thus the integrals cannot be solved except by giving "γ" every possible value in succession and treating it as a constant. Still, there are no known forms under which the integrals can be solved directly. This difficulty can always be got over by methods of approximation. By this means, Professor Bashforth has calculated tables ranging, more or less, from $\phi = 60°$ to $\phi = -60°$, and from $\gamma = 0$ to $\gamma = 5$ (*i.e.*, resistance at vertex = 5 times the weight of the projectile). Eq^n (*m*), & § 9. App. III. IV. & VI.

The symbols T, X, Y are merely abbreviations for the foregoing integrals; "γ," written beneath, denotes the particular value of "γ" to be used; and ϕ, ϕ' are the limits of integration.

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* Misprints in Bashforth:—

Last line but one in p. 52, "dp" should be omitted.

Equation (7) denominator should be $\{1-\gamma(3p+p^3)\}^{\frac{2}{3}}$.

Ex.—Suppose the angle of elevation 5°, and the position of the point to be required where the inclination is 4°. Suppose "γ" to be ·7.

Refer to p. 71, Table VI., where $\gamma = \cdot 7$. Instead of ${}^4X._7{}^5$ being given, we have the values of X from 0 up to 4° or 5°, &c.

$$\therefore -\frac{u_0^2}{g}({}^4X._7{}^5) = -\frac{u_0^2}{g}(\cdot 07366 - \cdot 09348) = \cdot 01982 \,.\, \frac{u_0^2}{g} = x.$$

Similarly for "y" and "t."

u_0 can be determined from equation (2), and thence $\gamma = \frac{2bu_0^3}{g}$ is also known.

Thus the reader has the materials for calculating trajectories, and it only remains to point out the system of work to be adopted—which is, it must be confessed, slightly tedious. A few preliminary remarks will be useful.

12. Remarks on "u_0," "$2b$," "K," &c.

If the reader will carefully study Art. 71, which gives the actual calculation of a trajectory, he will find several values for u_0, namely—

		f.s.
p. 60.	$u_0 =$	1025·5
p. 61.	$u_0 =$	1024·1
	$u_0 =$	1025·3
p. 62.	$u_0 =$	1027·1
	$u_0 =$	1031·9 (the calculated velocity at vertex),
	$u_0 =$	1026·4
	$u_0 =$	1021·8

all the values being obtained in the same example.

The explanation is this:—

See § 11. p. 177. In the consideration of each section of the trajectory, "u_0" enters into all the calculations; but this "u_0" is not the real velocity at the vertex, but what it would be if the coefficient of the resistance of the air remained constant up to the vertex, at the value adopted for the section.

Eqn (2). § 9. In the equation $\frac{1}{u^3} = \frac{1}{u_0^3} - \frac{2b}{g}(3p + p^3)$, the value obtained for u_0 evidently depends on the value given to $2b$, or to $K = (1000)^3\, 2b\, \frac{w}{d^2}$ the tabulated form.

Equation (2) may be written

$$\left(\frac{1000}{u}\right)^3 = \left(\frac{1000}{u_0}\right)^3 - \frac{K}{g}\frac{d^2}{w}(3p + p^3);$$

or, putting P for $(3p + p^3)$, the values of which are tabulated, we have the form best adapted for use— Tables III. & V.

$$\left(\frac{1000}{u}\right)^3 = \left(\frac{1000}{u_0}\right)^3 - \frac{K}{g} \cdot \frac{d^2}{w} P. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (n)$$

"K" can be obtained for any given velocity in Table I., but it is evident that for any section of the trajectory some mean velocity should be chosen to give the value of K.

For this purpose the velocity at the end of the section must be estimated, and K may be taken corresponding to the velocity intervening about one-third from the higher to the lower velocity. This is a very rough approximation, but it has been already remarked that slight errors in K are of very trivial consequence in the results. § 9.

If greater accuracy is required, the velocity at the end of the section may be roughly calculated with the approximate value of K, and then the mean of all values of K for the intermediate velocities can be taken as the basis for the more accurate calculation.

Thus (Art. 71), $u_5 = 1329{\cdot}9$, $u_4 = 1238{\cdot}5$. Take the mean of the ten values of K for the velocities intermediate to 1240 and 1330 (both inclusive), which is 108. Or, in like manner, the mean of $\log \frac{K}{g}$ might be found to be ·52618—which would, however, be but very slightly more accurate than ·5253, which is the value used.

It will be seen that the trajectory is divided into sections, sometimes of 1°, sometimes of 2° (*i.e.*, 1° or 2° change of inclination). The length that ought to be adopted depends upon the degree of rapidity with which K alters. If K is nearly constant, a large section may be chosen. With an initial* velocity of 1300 f.s., 3° would not be too large an interval, since the velocity at the end would probably be about 1100 and K would be nearly constant throughout; but the next section ought not to exceed 1°, because the velocity would be less and rate of variation of K greater. Thus, to ensure accuracy, smaller intervals should be adopted for the descending than for the ascending branch. If larger intervals are used, more care must be taken in choosing the mean value for K; however, the latter portion of the trajectory need not be calculated with quite as much care as the first portion—any error in which affects the whole of the succeeding portions. It is for this reason that larger intervals are used for the descending branch in Art. 71. Table I.

13. Calculation of Trajectories.

Formulæ for ascending branch:—

$$\left(\frac{1000}{u_0}\right)^3 = \left(\frac{1000}{u}\right)^3 + \frac{K}{g}\frac{d^2}{w} P, \text{ to find } u_0, \qquad \text{Eq}^{\text{n}}\ (n).$$

$$\left(\frac{1000}{u}\right)^3 = \left(\frac{1000}{u_0}\right)^3 - \frac{K}{g}\frac{d^2}{w} P, \text{ to find } u \text{ at end of section,} \qquad \text{Eq}^{\text{n}}\ (n).$$

$$\gamma = \frac{2bu_0^3}{g} = \frac{K}{g} \cdot \frac{d^2}{w}\left(\frac{u_0}{1000}\right)^3. \qquad \text{Eq}^{\text{n}}\ (m).$$

* *i.e.*, horizontal component of initial velocity.

Take the example in Art. 71.

$$\text{Here } V = 1335,$$

$$\text{angle of projection} = 5^\circ;$$

$$\therefore\ u_5 = 1335 \cos 5^\circ = 1329{\cdot}9,$$

$$\frac{d^2}{w} = \frac{\overline{6{\cdot}34}|^2}{70{\cdot}6} = {\cdot}56935.$$

Let the sections be of 1° interval.

(1) Estimate mean velocity for K at 1300, $\therefore K = 107{\cdot}9$.

(2) $$\therefore \left(\frac{1000}{u_0}\right)^3 \text{ is known} = \left(\frac{1000}{u_5}\right)^3 + \frac{K}{g} \cdot \frac{d^2}{w} \cdot P_5$$

$$= \left(\frac{1000}{1329{\cdot}9}\right)^3 + 3{\cdot}352 \times {\cdot}56935 \times P_5$$

$$= {\cdot}92736.$$

The logarithms of $\frac{K}{g}$ and of P_5 are given in Tables I. & III.

$$\therefore\ u_0 = 1025{\cdot}5.$$

(3) $$\therefore\ \gamma = \frac{K}{g} \cdot \frac{d^2}{w} \times \frac{1}{{\cdot}92736} = 2{\cdot}058.$$

(4) $${}_5x_4 = \frac{u_0^2}{g}\,({}^5X_{2\cdot058}{}^4).$$

p. 81, Table VI. Now, $${}^5X_2{}^4 = {\cdot}10992 - {\cdot}08294 = -{\cdot}02698,$$

$${}^5X_{2\cdot1}{}^4 = {\cdot}11167 - {\cdot}08383 = -{\cdot}02784,$$

$$\therefore\ {}^5X_{2\cdot058}{}^4 = -{\cdot}02698 + {\cdot}58 \times {\cdot}00086^* = {\cdot}02748,$$

$$\therefore\ {}_5x_4 = 897{\cdot}7 \text{ ft.}$$

Similarly, $${}_5y_4 = 70{\cdot}8,$$

$${}_5t_4 = {\cdot}7''.$$

(5) $$\left(\frac{1000}{u_4}\right)^3 = \left(\frac{1000}{u_0}\right)^3 - \frac{K}{g} \cdot \frac{d^2}{w} \cdot P_4$$

$$= {\cdot}52635;$$

$$\therefore\ u_4 = 1238{\cdot}5.$$

(6) Estimate afresh for K, and proceed as before.

For the descending branch, ϕ is negative;

$\therefore\ p = \tan\phi$ is negative,

$\therefore\ P = (3p + p^3)$ changes its sign.

---

* By proportional parts: ·00086 is the difference between ·02698 and ·02748.

Starting from the vertex, we know "u_0" and $\left(\frac{1000}{u_0}\right)^3$; and the steps now are:—

(1) Estimate for K; mean velocity $= 1010$, $\therefore K = 77{\cdot}5$.*

(2) Calculate γ.

(3) Calculate ${}_0x_2$, ${}_0y_2$, ${}_0t_2$.

(4) $\left(\frac{1000}{u_2}\right)^3 = \left(\frac{1000}{u_0}\right)^3 + \frac{K}{g} \cdot \frac{d^2}{w} P_2$;

$\therefore u_2 = 982{\cdot}7$.

(5) Estimate again for K; mean velocity $= 970$, $\therefore K = 69{\cdot}6$.*

(6) $\left(\frac{1000}{u_0}\right)^3 = \left(\frac{1000}{u_2}\right)^3 - \frac{K}{g}\frac{d^2}{w} P_2$.

This gives the new value of u_0, and the next section is similarly determined.

Thus there are five distinct steps for each section, involving only arithmetic and logarithmic computation.

The most laborious step is the calculation of x, y, and t, especially when very great accuracy is required, and interpolation, instead of proportional parts, is used for intermediate values of γ or ϕ not given in the tables. The next section will give a brief account of one of twelve trajectories, in calculating which the writer of this paper expended a great deal of unnecessary labour by aiming at too great accuracy, and always interpolating when the differences were not regular; whereas the advantage obtained in the way of accuracy was entirely neutralised by the slight inaccuracies due to the values taken for K being necessarily, to a certain extent, incorrect.

14. Problem on Trajectories.

The following problem was put to the writer:—

At what distances from the muzzle of the gun will a 9-pr. and 16-pr. projectile be at heights above the muzzle of 2 ft. 3 ins. and 5 ft. 3 ins. (both in the ascending and descending branch), it being considered that at these heights respectively a man on foot and on horseback would be just cleared; elevation to be taken at 1°, 2°, 4°, 6° in succession? (*Vide* diagram.)

The solutions obtained for the whole problem agreed well with what was to be expected in each case, and these notes are the result of the experience gained in working them out.

Take the case of the 16-pr. at 4° elevation.

$$w = 16 \text{ lbs.}, \quad d = 3{\cdot}54'', \quad V = 1355.$$

* The corrected values would be 80·1 instead of 77·5, and 71·1 instead of 69·6.

The principal steps gave the following results:—

4° to 2°:

$u_4 = 1351{\cdot}7$, mean vel. for $K = 1290$,

$\left(\frac{1000}{u_0}\right)^3 = {\cdot}95755$, $\therefore\ u_0 = 1014{\cdot}56$,

$\gamma = 2{\cdot}7467$ $\begin{cases} \phi = 3{\cdot}9525^\circ \text{ gives } y = 2\tfrac{1}{4} \text{ ft., } x = 32{\cdot}606 \text{ ft.} \\ \phi = 3{\cdot}92275^\circ \text{ " } y = 5\tfrac{1}{4} \text{ ft., } x = 75{\cdot}762 \text{ ft.} \end{cases}$

${}_4x_2 = 1653$ ft., ${}_4y_2 = 88{\cdot}293$ ft.

2° to 0°:

$u_2 = 1136{\cdot}1$, mean vel. for $K = 1100$,

$\left(\frac{1000}{u_0}\right)^3 = {\cdot}952205$, $\therefore\ u_0 = 1016{\cdot}46$ (true vel. at vertex).

$\gamma = 2{\cdot}6934$, ${}_2x_0 = 1246{\cdot}56$, $y = 22{\cdot}584$,

$\therefore\ {}_4x_0 = 2899{\cdot}56$, total height $= {}_4y_0 = 110{\cdot}877$.

0° to 2°:

Mean vel. for $K = 990$,

$\gamma = 1{\cdot}86$, ${}_0x_2 = 1060{\cdot}14$, ${}_0y_2 = 18{\cdot}071$.

2° to 4°:

$u_2 = 957{\cdot}87$, mean vel. for $K = 940$,

$\left(\frac{1000}{u_0}\right)^3 = {\cdot}972001$, $\therefore\ u_0 = 1010{\cdot}29$,

$\gamma = 1{\cdot}667$, ${}_2x_4 = 951{\cdot}02$, ${}_0y_2 = 49{\cdot}576$.

4° to end:

$u_4 = 913{\cdot}34$, mean vel. for $K = 900$,

$\left(\frac{1000}{u_0}\right)^3 = {\cdot}983261$, $\therefore\ u_0 = 1005{\cdot}64$,

$\gamma = 1{\cdot}5937$,

Remaining height $= 43{\cdot}23$,*

${}_4y_{5\cdot21144} = 43{\cdot}23$ ${}_4x_{5\cdot21144} = 537{\cdot}62$

$\quad\quad\quad\quad\ \ 2{\cdot}25$

${}_4y_{5\cdot1546} = 40{\cdot}98$ ${}_4x_{5\cdot1546} = 512{\cdot}99$

$\quad\quad\quad\quad\ \ 3$

${}_4y_{5\cdot07727} = 37{\cdot}98$ ${}_4x_{5\cdot07727} = 479{\cdot}41$

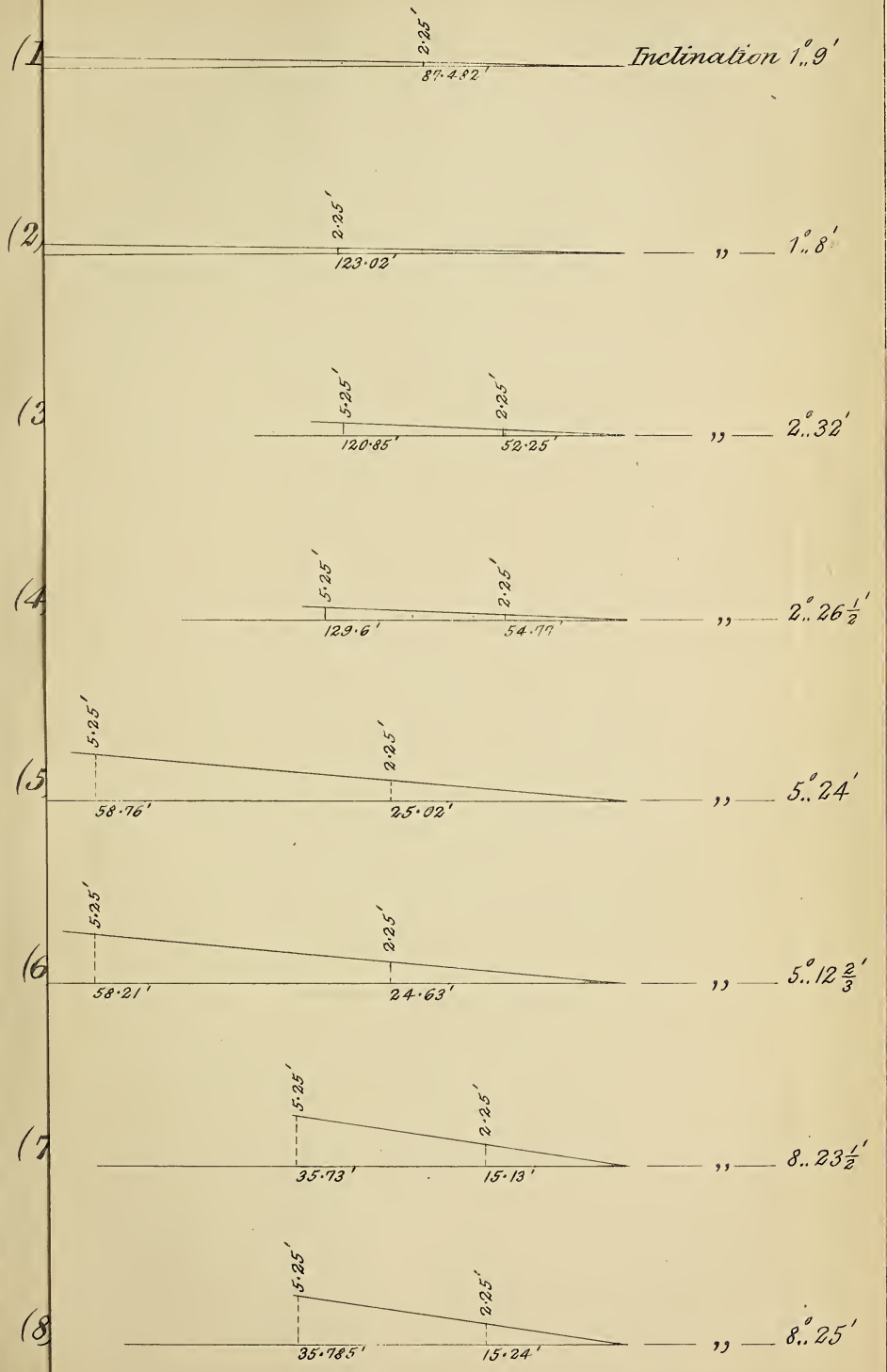
${}_0y_2 = 18{\cdot}071$
${}_2y_4 = 49{\cdot}576$
* $43{\cdot}23$
Tot. $110{\cdot}877$

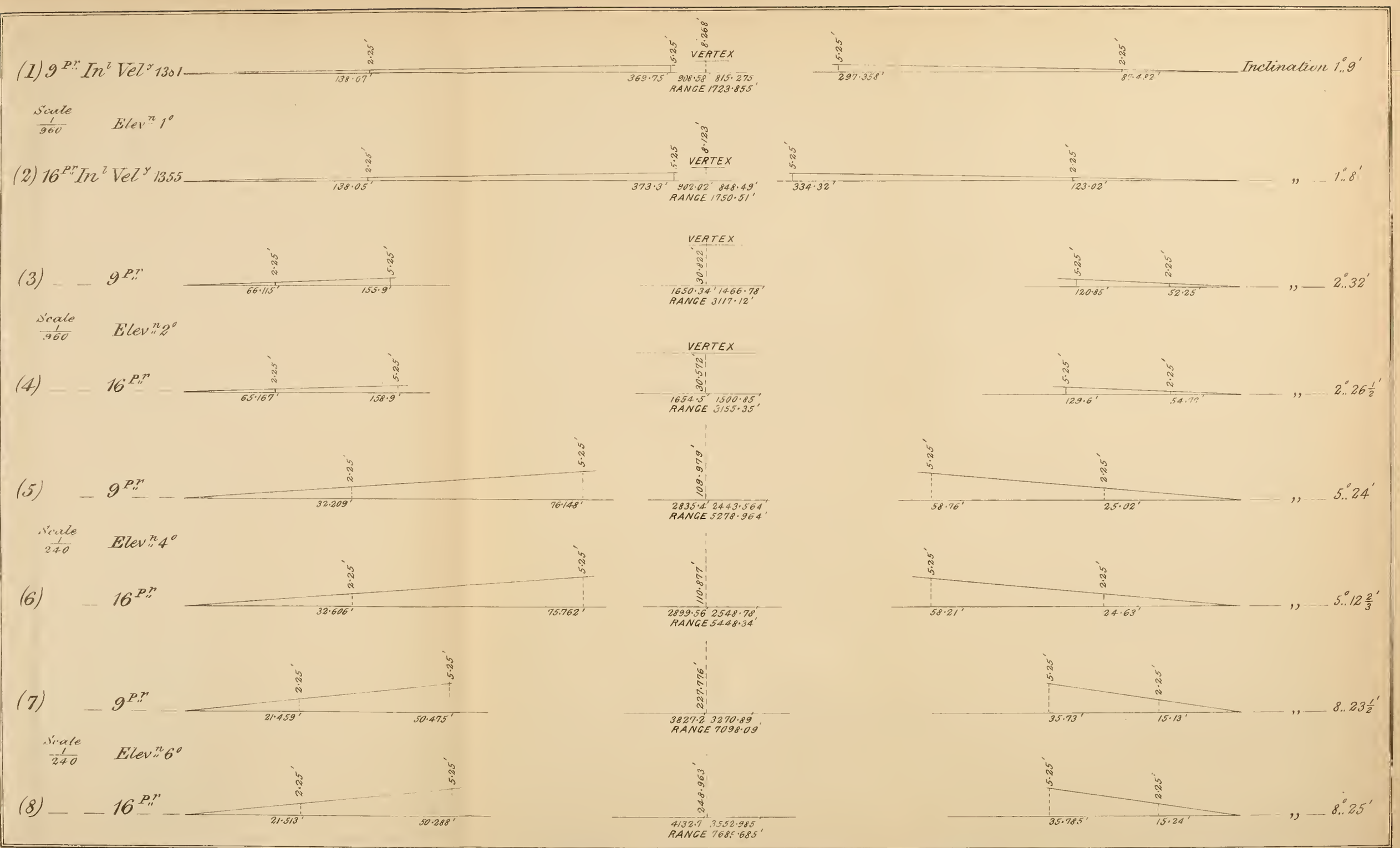
The result of the foregoing is as follows:—

Projectile reaches a height of—

ft.		ft.		
$2\frac{1}{4}$	at	32·606 from gun,		$\phi = 3{\cdot}9525^\circ$
$5\frac{1}{4}$	"	75·762	"	$\phi = 3{\cdot}92275^\circ$
110·877 (vertex)	"	2899·56	"	$\phi = 0^\circ$
	"	2548·78 from end of range,		
$5\frac{1}{4}$	"	58·21	" "	$\phi = 5{\cdot}07727^\circ$
$2\frac{1}{4}$	"	24·63	" "	$\phi = 5{\cdot}1546^\circ$
0	"	5448·34 from gun,		$\phi = 5{\cdot}21144^\circ$
				$= 5^\circ\ 12\frac{2}{3}'$

N.B.—The range tables give 1900 yds.


(1
2·25′
87·482′
Inclination 1°.. 9′
(2
2·25′
123·02′
" 1°.. 8′
(3
5·25′
2·25′
120·85′
52·25′
" 2°.. 32′
(4
5·25′
2·25′
129·6′
54·77′
" 2°.. 26½′
(5
5·25′
2·25′
58·76′
25·02′
" 5°.. 24′
(6
5·25′
2·25′
58·21′
24·63′
" 5°.. 12⅔′
(7
5·25′
2·25′
35·73′
15·13′
" 8.. 23½′
(8
5·25′
2·25′
35·785′
15·24′
" 8°.. 25′


(1) 9 Pr. Inl Velv 1301
Inclination 1°.9'
Scale 1/960
Elevn 1°
(2) 16 Pr. Inl Velv 1355
" 1°.8'
(3) 9 Pr.
" 2°.32'
Scale 1/960
Elevn 2°
(4) 16 Pr.
" 2°.26½'
(5) 9 Pr.
" 5°.24'
Scale 1/240
Elevn 4°
(6) 16 Pr.
" 5°.12⅔'
(7) 9 Pr.
" 8°.23½'
Scale 1/240
Elevn 6°
(8) 16 Pr.
" 8°.25'
VERTEX
RANGE 1723·855'
RANGE 1750·51'
RANGE 3117·12'
RANGE 3155·35'
RANGE 5278·964'
RANGE 5448·34'
RANGE 7098·09'
RANGE 7685·685'

The following table shows the ranges (in feet), calculated in the above manner, compared with those given in the tables :—

Gun.	Elev.	Range.		Gun.	Elev.	Range.	
		calculated.	in table.			calculated.	in table.
	°				°		
16-pr.	1	1750·51	2100	9-pr.	1	1723·855	2000
"	2	3155·35	3500	"	2	3117·12	3300
"	4	5448·34	5700	"	4	5278·964	5400
"	6	7685·685	7650	"	6	7098·09	7050

The calculated ranges are less than those given in the range tables,* owing to the height of the muzzle of the gun above the level of the horizontal plane not having been considered. Of course the difference is considerably more for low elevations than for high ones, when it becomes immaterial. This will be evident after studying the accompanying diagrams of the calculated trajectories. For a drop of $5\frac{1}{4}$ ft. at the end of the trajectory we have for increase of range about 300 ft. when firing at 1° elevation, but only 35 ft. at 6°.

It will be interesting to make some comparisons between the trajectories of the two guns. For short distances from the muzzle, it would appear (*vide* diagram) that the 9-pr. has the flatter trajectory, owing to its higher initial velocity, but afterwards the greater weight of the 16-pr. gives it the advantage; for

$$\text{resistance of air varies as } \frac{d^2}{w},$$

$$\text{and } w \text{ varies as } d^3,$$

$$\therefore \text{ resistance varies as } \frac{1}{d};$$

i.e., the greater the calibre the less the resistance.

Thus in every case here calculated the 16-pr. has the longer range, but in cases (1) to (4) it attains a lower vertical height than the 9-pr.; so also it descends at a less angle—except when firing at so high an angle as 6°, when, in consequence of the great difference in range (about 600 ft.), it is natural to expect a greater angle of fall; but the difference is very slight. This illustrates the very great advantage to be derived by diminishing the proportions between calibre and weight of projectile.

Some slight inconsistencies may be observed in these diagrams—seldom, however, amounting to more than a decimal of a foot. They are due to the values selected for K not having been absolutely correct.

In some instances, K was required for lower velocities than those given in Table I. The following values were used, which were estimated from the average law of variation in the table. They may be of

* Except at 6° elevation.

use to the reader, but they must not be relied upon as being absolutely correct; correct values could only be obtained by actual experiments:—

V.	$\frac{K}{g}$	$\log \frac{K}{g}$
800	1·921	·2835
810	1·926	·2847
820	1·932	·2860
830	1·938	·2873
840	1·944	·2887
850	1·951	·2903
860	1·959	·2920
870	1·968	·2940
880	1·978	·2962
890	1·989	·2986

15. Derivation of Elongated Projectiles.

(Articles 73, 74.)

These articles are at the end of the chapter on the motion of a projectile in a resisting medium. Attention is therefore drawn to them, lest they should be overlooked.

Chap. V.

16. Rectilinear Motion in a Resisting Medium.

By considering the motion of a projectile to take place in a straight line, very close approximations can be obtained for the time of flight and horizontal range in terms of the velocities. The error is represented by the difference between the lengths of the arc and chord of the trajectory.

We have the differential equations

Eq^{n} (*c*).
$$f = \frac{d^2s}{dt^2}, \text{ or } \frac{dv}{dt}, \text{ or } v\frac{dv}{ds}.$$

Also $f = -2bv^3$.

We want to obtain relations between t and v, s and v, s and t; and must choose our differential equations accordingly.

1st. $$\frac{dv}{dt} = -2bv^3; \quad \therefore -\frac{dv}{v^3} = 2bdt,$$

$$\therefore \text{ (integrating), } \frac{1}{2v^2} - \frac{1}{2V^2} = 2bt;^*$$

for when $t = 0$, $v = V$ (the initial velocity).

* Misprint in Bashforth, p. 67, 6th line from bottom:—"$C = \frac{1}{2}V^2$" should be "$C = \frac{1}{2V^2}$.

Whence we have, putting $K = 2b\frac{w}{d^2}(1000)^3$,

$$\frac{d^2}{w}t = \frac{500}{K}\left\{\left(\frac{1000}{v}\right)^2 - \left(\frac{1000}{V}\right)^2\right\} \text{.....(1)}$$

$$\text{2nd.}\quad v\frac{dv}{ds} = -2bv^3;\quad \therefore\ -\frac{dv}{v^2} = 2bds,$$

$$\therefore\ (\textit{integrating}),\quad \frac{1}{v} - \frac{1}{V} = 2bs;\ \text{for } v = V \text{ when } s = 0.$$

$$\text{Whence}\quad \frac{d^2}{w}s = \frac{(1000)^2}{K}\left(\frac{1000}{v} - \frac{1000}{V}\right). \text{.....(2)}$$

In order to obtain the relation between s and t, we must substitute $\frac{ds}{dt}$ for v in some one of the foregoing equations which will answer the purpose.

$$\text{Take}\quad \frac{1}{v} - \frac{1}{V} = 2bs,$$

$$\therefore\ \frac{dt}{ds} - \frac{1}{V} = 2bs;\quad \therefore\ dt = \left(\frac{1}{V} + 2bs\right)ds,$$

$$\therefore\ t = \frac{s}{V} + bs^2. \text{.....(3)}$$

Again, dividing (1) by (2), we have

$$\frac{1}{v} + \frac{1}{V} = \frac{2t}{s}. \text{.....(4)}$$

Values of $\frac{d^2}{w}t$ and $\frac{d^2}{w}s$—from equations (1) and (2)—have been tabulated for all velocities— General Tables VIII. to XI.

from 500 to 1900 f.s. for elongated projectiles,
" 540 " 1700 " spherical "

The numbers against each velocity (read as in log. tables), represent $\frac{d^2}{w}$ multiplied by the space or time passed by the projectile whilst the velocity is reduced from the highest velocity given, to the one corresponding to the number taken.

The difference between any two numbers in the same table gives the result for the reduction of the higher velocity to the lower.

An idea may be obtained of the amount of accuracy to be looked for by comparing some calculation by the General Tables with a trajectory carefully worked out.

As an example, take the 16-pr. and the horizontal distance to the vertex—already calculated to be 2899·56 ft. § 14.

The velocity is reduced from 1355 to 1016·46,

$$\therefore\ s = \frac{w}{d^2} \times (3952 - 1574) = \frac{16}{3{\cdot}54^2} \times 2378 = 3036 \text{ ft.}$$ Table VIII.

This result, being the length of the arc, is—as was to be expected—greater than the true one, but only by $136\frac{1}{2}$ ft.

§ 14. Again, suppose the velocity to be required after a distance of 1653 (*i.e.*, when inclination is 2°),

$$\frac{d^2}{w} s = \frac{\overline{3{\cdot}54}|^2}{16} \times 1653 = 1294{\cdot}63.$$

Add this to the number 1574, against vel. 1355, and we get 2868·63, against which we find the required velocity, 1139·23 (using propor-
§ 14. tional parts). The calculated velocity was 1136·1 sec 2° = 1136·8—very slightly different.

These instances have been selected hap-hazard, and not because they were found to agree well.

The tables for $\frac{d^2}{w} t$ are used in precisely the same manner.

It must be clearly understood that in all these tables and calculations the multiplier $\frac{d^2}{w}$ is only used to enable one set of tables to hold for all calibres.

Chap. VI. 17. Law of Penetration of Projectiles.

(Chapter VI.)

In Art. 83, λ and μ are merely put for $\frac{\pi a}{4}$ and $\frac{\pi \beta}{4}$ respectively. It must not be forgotten that

See eq^n (a). $$R = Mf \text{ and } W = Mg;$$

where R is the resistance and f the retarding force or retardation produced by R in a unit of time.

Art. 83. $$\therefore f = \frac{R}{M} = \frac{g}{w} \cdot R = \frac{g}{w} \cdot d^2 (\lambda + \mu v^2).$$

The forms of integration required for the following are

$$\int \frac{dx}{x} = \log x,$$

$$\int \frac{dx}{a^2 + x^2} = \frac{1}{a} \tan^{-1} \frac{x}{a}.$$

Now, $$f = v \frac{dv}{ds} = -\frac{gd^2}{w} (\lambda + \mu v^2);$$

$$\therefore \frac{vdv}{\lambda + \mu v^2} = -\frac{gd^2}{w} ds,$$

$$\therefore \frac{1}{2\mu} \cdot \frac{d(\lambda + \mu v^2)}{\lambda + \mu v^2} = -\frac{gd^2}{w} ds,$$

$$\therefore \log \frac{\lambda + \mu v^2}{\lambda + \mu V^2} = -\frac{2\mu g d^2}{w} \cdot s; \text{ for } v = V \text{ when } s = 0. \quad \ldots\ldots(p)$$

N.B.—2·3026 = $\log_e 10$; hence follows eq^n (1) in Bashforth.

Again, $$f = \frac{dv}{dt} = -\frac{gd^2}{w}(\lambda + \mu v^2),$$ Art. 85.

$$\therefore \frac{\frac{1}{\sqrt{\mu}} \cdot d(v\sqrt{\mu})}{\lambda + \overline{v\sqrt{\mu}}|^2} = -\frac{gd^2}{w}dt,$$

$$\therefore \frac{1}{\sqrt{\mu}} \cdot \frac{1}{\sqrt{\lambda}}\left(\tan^{-1}\frac{v\sqrt{\mu}}{\sqrt{\lambda}} - \tan^{-1}\frac{V\sqrt{\mu}}{\sqrt{\lambda}}\right) = -\frac{gd^2}{w} \cdot t;\ \text{for } v = V \text{ when } t = 0 \ldots (q)$$

Equations (p) and (q) give the length and time of penetration whilst the velocity is reduced from V to v.

"Vis viva" is a term used to express the mass of a body multiplied by the square of its velocity. When the velocity is reduced from V to v, the loss of *vis viva* is $M(V^2 - v^2)$; where $M = \text{mass} = \frac{w}{g}$. Art. 87.

The "work done" is half the loss of *vis viva.*

The ordinary expression for volume of revolution is ${}^0\int^x \pi y^2 dx$, but here the notation "s" is used in exactly the same sense as "x."

Hence the equation

$$\frac{1}{2}\frac{w}{g}(V^2 - v^2) \propto {}^0\int^s y^2 ds = k\ {}^0\int^s y^2 ds;$$

where k is some constant depending on the nature of the earth and on the form of the projectile.

Conclusion.

The object of Professor Bashforth was to calculate the motion of projectiles in air, and the chapter on motion in vacuo was only introductory. These notes, therefore, have only referred to the symbols "$2b$," "X," "Y," "T," with reference to the articles on motion in air; for any previous explanation of them would have had to be repeated. If, however, the writer has succeeded in removing difficulties, the symbols ${}^aX_0^\theta$, &c., in Art. 35 will be perfectly intelligible; of course $\gamma = 0$, since there is no resistance. These symbols are merely used in this article for the sake of symmetry with Art. 63, § 11. although the integrals they express are easily solved. Chap. II.

With regard to "$2b$," this symbol is first used in Art. 44; consequently this passage may cause difficulties to those who are reading the book for the first time. The whole investigation of the law of resistance in Chap. III. must be first studied, and then it will be seen that $2bl^2$ is the same as $\Delta^2 t$, since $2b$ has been put for the numerical value of $\frac{\Delta^2 t}{l^2}$. Hence the fourth column of figures in Art. 44 is merely a table of half the second differences of the times. The last column is a table of $\frac{K}{\overline{1000}|^2}$, since $K = \overline{1000}|^3\ 2b\frac{w}{d^2}$. Art. 55. § 9.

Equation (V.) in Appendix III. is worth studying with regard to its

application to the solution of integrals by approximation, but those who are possessed of sufficient mathematical knowledge to enter upon this will need no further assistance.

In conclusion, the writer begs to offer some extracts, with remarks, which have been made by a friend from the writings of the famous Russian General Mayevski—who has contributed so much to artillery science.

The information supplied by the following extracts may be of interest to the artillerist:—

General Mayevski was appointed Professor of Ballistics to the Russian Academy of Artillery in 1858. He made much use of General Didion's "Traité de Balistique" in composing his own work on that subject, which was published in 1870 in the Russian language at the expense of the state. A translation into French of the more important chapters of the work was printed in St. Petersburg, and published in Paris in 1872.

General Mayevski observes:—"La description des expériences sur la résistance de l'air au mouvement des corps animés de faibles vitesses, ainsi que des expériences faites en 1840 sur la résistance de l'air au mouvement des projectiles a été tirée du traité de M. Didion. Les résultats des expériences faites par M. Bashforth en Angleterre sur les projectiles oblongs ont été déduits des données insérées dans les *Proceedings of the Royal Artillery Institution*, Woolwich, 1868."—Preface p. vi. And again:—"Aussi pour compléter les données se rapportant aux projectiles de forts calibres nous avons profité des tableaux des vitesses décroissantes déduites par M. Bashforth de ses expériences faites en 1868 au moyen de son chronographe; ces tableaux comprennent les vitesses de $518^{m:s}$ a $283^{m:s}$ (1700 f.s. to 928 f.s.) qui correspondent aux trajets de 305 en 3050 mètres des projectiles oblongs de 178^{mm}, 203^{mm}, et 229^{mm}, et qui sont obtenues pour le cas où le mouvement des projectiles peut être consideré comme rectiligne. Nous avons calculé d'après les résultats insérés dans ces tableaux les valeurs de la résistance correspondantes à differentes vitesses."—p. 58.

Reference is here made to some results communicated to the Royal Artillery Institution by Captain Ford, R.A., and published in "Short Notes" for October, 1868, pp. 69, 70, in the form of tables showing the velocities of the service shot for 9-in., 8-in., and 7-in. M.L. rifled guns at intervals of 100 ft., &c. From these it was easy to deduce the values of M. Didion's ρ'. The reports in full of the experiments made with the Bashforth chronograph were not published till late in 1870.

Respecting the law of the resistance of the air to elongated projectiles, Mr. Bashforth observed that "for ogival-headed, elongated shot, the resistance of the air may be considered to vary roughly as the *sixth* power of the velocity for velocities 900–1100 f.s., to vary as the *third* power for velocities 1100–1350 f.s., and to vary as the *second* power for velocities above 1350 f.s."—*Tables of Remaining Velocity, &c.*, p. 21 (1871), and *Proceedings of the R.A. Institution*, p. 367 (for Sept. 1871).

This may be compared with General Mayevski's conclusions, stated in his Preface, p. vi.:—"A fin que les expressions de la résistance représentent, avec une approximation suffisante, les resultats de nos expériences et ceux des expériences anglaises, faites avec des appareils perfectionnés, et que ces expressions permettent en même temps une intégration facile, quoique par approximation, des équations différentielles du mouvement, nous avons admis *pour les projectiles spheriques*.....

pour les projectiles oblongs, quand leur axe de figure coïncide avec la direction du mouvement, nous avons admis, dans les limites des vitesses de $510^{m:s}$ à $360^{m:s}$ (1673 f.s. to 1181 f.s.) la résistance de l'air proportionelle au carré de la vitesse; dans les limites des vitesses de $360^{m:s}$ à $280^{m:s}$ (1181 f.s. to 919 f.s.) nous avons admise proportionelle à la sixième puissance de la vitesse," &c.

In the theoretical treatment of the motion of a projectile, General Mayevski changes his *law* of resistance according to the velocity of the moving shot, while Mr. Bashforth uses the cubic law of resistance throughout, changing only the coefficient to suit the velocity.

Professor Hélie, from experiments made with elongated shot, moving with velocities $340^{m:s}$ to $200^{m:s}$ (1115 f.s. to 656 f.s.), deduced a law of resistance which varied as the *cube* of the velocity, while the two more recent experimenters agree in giving the *sixth* power of the velocity as the best law when only one term is used, for this limit of velocity.

BRONZE STEEL.

BY

CAPTAIN J. F. OWEN, R.A.

Experiments lately carried out in Austria, at the instance of General Von Uchatius,* with an alloy of copper and tin, cast under certain conditions, and termed by him "bronze steel," are of so interesting a nature, and may have so important an issue that no apology is needed for giving in this paper a resumé of the results thus far obtained.

Before describing these experiments, it may not be amiss to review shortly the employment of bronze for the construction of rifled ordnance, to show why it has fallen into disfavour for that purpose, and to point out the reasons which in recent times have led to a partial and temporary return to that alloy, as a gun metal, by powers which had rejected it in the first instance as unfit for rifled guns.

About the middle of this century, and immediately before the introduction of rifling, field ordnance consisted almost universally of bronze,* while the first rifled field pieces used in actual warfare were the "Napoleon" shell guns, also of bronze, which played so important a part in the Italian campaign of 1859, at the battle of Solferino.

The example of France in thus utilizing her S.B. bronze guns for the manufacture of rifled field pieces was sooner or later followed by all the Continental Powers, Prussia excepted; England however used other materials, while the Northern Kingdoms of Denmark, Sweden and Norway retained cast iron.†

For siege rifled guns and guns of position, bronze is largely used on the Continent, and in the war of 1870-71 a great proportion of the Prussian siege train was composed of such ordnance.

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* Colonel in the Austrian Artillery, Major-General and Director of the Arsenal at Vienna.

† The field smooth-bore ordnance of Norway, Denmark, and Sweden, was of cast iron, which is the material still used for rifled field guns in these kingdoms; it is of excellent quality and very cheap, a 3".24 gun with 18-pr. projectile costing only £23 4s., but of course the charges used are low, so that these pieces are not powerful guns, giving an initial velocity of not more than 1200 fs.

Prior to the advent of rifled guns, it had been frequently proposed in Prussia to employ a lighter and stronger metal than bronze for field guns, in order to increase their mobility. Between 1844 and 1855 several steel S.B. field pieces were manufactured for trial, both at Bochum and also by Messrs. Krupp, at Essen, and on account of the good results given by these guns, an experimental committee actually prepared designs in 1857 for a service S.B steel gun of 12 centimetre calibre, and to fire charges of between $3\frac{1}{2}$ and $4\frac{1}{2}$ lbs.

When therefore it became evident that rifled guns must take the place of smooth-bores and that a new armament had to be provided, Prussia was naturally ready to adopt for that armament a metal which had been proved, even for the old guns, to be better than bronze. The enterprising firm of Krupp completed in 1856 a 9c (3·2-inch) rifled steel gun, according to the designs of an artillery committee, which was so satisfactory, that in 1859 steel was definitely adopted by the Prussian authorities as the material to be used for the new field guns. For the sake of economy, attempts were at the same time made to utilize the existing 12c and 9c S.B. bronze guns by rifling them; these attempts failed and in 1865, all the rifled Prussian field pieces—9c and 8c guns—were made of steel, while the 12c S.B. of bronze were also retained, the latter piece was the Horse Artillery Gun employed by Prussia in the campaign of 1866.

In England bronze was not considered of adequate strength, and the distinguished engineer, Sir W. Armstrong, having constructed a rifled gun of wrought iron as early as 1854, and having matured a satisfactory method of manufacture, his system was adopted to satisfy the imminent necessity that existed for an immediate supply of rifled field pieces. His first guns were made entirely of wrought iron, but many of the later Armstrong field guns have steel barrels. To these two metals iron and steel we have steadily adhered in the manufacture of our field ordnance with the partial exception mentioned further on.

With S.B. bronze guns much inconvenience was occasioned by the softness of that alloy, especially when heated by rapid firing,* and as experience was gained concerning rifled ordnance in the field, it was found that the defects inherent to ordinary bronze were still more serious in such pieces. Their accuracy was affected by much firing, and the greater pressure in the powder chamber quickly developed flaws by burning out the tin spots.† The cutting of the grooves also laid bare many of these spots, which otherwise would not have been apparent.

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* In his "Employment of Artillery," Sir John May tells us that in the first siege of Badajos by our forces in 1811, we had to borrow from the Portuguese a siege train of bronze ordnance. The rapid firing of these pieces soon disabled 18 out of 40 guns, and the siege was consequently raised. Shortly afterwards, in 1812, we again attacked that fortress, but with an English siege train of iron ordnance, when it soon fell into our hands.

† "Tin spots," so called, being patches or veins of white alloy, rich in tin, always found in ordinary bronze. Such patches are burnt away with a comparatively small amount of heat, they are harder than bronze.

To reap the full advantages of rifling, it became evident that some better material than bronze would have to be employed in the construction of field guns.* Various attempts have been made to discover a modification of bronze, or some analogous alloy, sufficiently hard, elastic, and strong for the purpose required, but as yet, unless bronze steel be a success, all these attempts have failed.†

France, Italy, Spain and Austria are therefore turning their attention to steel as a metal for their field armament while Russia has already supplied herself with many steel field pieces. Switzerland retains bronze for her new 8c guns, pattern 1871; apparently for reasons of economy: the great objection to steel on the part of the first-mentioned powers is that their native industry cannot as yet supply them with this metal of the quality needed, in the required quantity, nor with sufficient rapidity.

France has consequently adopted the new Reffye B.L. bronze gun, using a metallic cartridge, in hopes that her steel manufacturers will be able to supply her wants when she has finally settled upon the nature of her future field pieces.

It seemed certain, however, a short time ago, that both Italy and Austria would be obliged to have recourse to Messrs. Krupp, who possess a gigantic monopoly of steel gun manufacture on the Continent.‡ Italy proposes to spend the sum of 4,500,000 francs in purchasing 8.7c steel Krupp's guns to replace her 12c R.M.L. of bronze, while Austria has been experimenting with the same nature of gun, and found it so superior to her 8-pr. rifled muzzle-loader, that she too was unwillingly preparing for the enormous outlay of 3 or 4 million pounds for a similar purpose, when the researches of General Von Uchatius held out hopes that an improved description of bronze and native manufacture might yet be employed to provide her with efficient rifled field armament.

Although, as we have seen the tendency of those European powers which have hitherto used bronze for field pieces, is to replace that material by steel, yet in both England and Prussia a return has been at times made to bronze rifled field guns.

Thus in Prussia in 1866, several 8c steel guns burst at practice, and this, together with the reports of Artillery Officers, regarding the uncertainty of Krupp's steel, engendered so much distrust as to that metal, that further experiments were carried out with bronze guns of 8c and 9c in 1866–67, when they stood the tests of trial very satisfactorily, and were not so much damaged by case shot as was expected.

A number of bronze 8c were consequently made for batteries of the

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* All these defects of bronze for the bore of a gun, irrespective of strength,—viz., melting of the tin, change of figure, the conversion, abrasion and compression—obviously aggravate each other; and when taken in connection with rifling and excessive pressures, are conclusive evidence as to the unfitness of the material to meet the conditions of greatest effect. "Holley—Construction of Artillery."

† *Vide* pp. 196 and 197.

‡ Messrs. Krupp, it is stated can deliver over 200 field guns a month.

reserve, and were, we are told, received with much satisfaction by the men; of these a few were employed during the war of 1870–71.* During this war however, the steel field pieces acquitted themselves so well, that the artillery regained their confidence in that metal, which has consequently triumphed in Prussia, the bronze guns upon further trial having shown themselves very inferior to what was expected from the behaviour of the experimental guns.

We ourselves also reintroduced the employment of bronze for a short period, though for reasons differing from those of the Prussian authorities. It was not that confidence had been lost in the materials of which our field pieces were made, but that the Armstrong system of breech-loading, upon which these guns were constructed, had exhibited many defects when exposed to the test of war in China and elsewhere.

As it was plain that a new mode of construction had to be decided upon and † various committees of distinguished artillery officers having reported in favour of adopting muzzleloading guns, both on account of their simplicity and freedom from the faults inherent to all B.L. guns and also from the possibility of employing with them an efficient time fuze; it was urged by some that bronze should be employed as a material for these pieces, not only on economical grounds, but especially for Indian service, so that guns might be made in that great dependency without the necessity for sending out expensive plant.

It would of course be advantageous that our Indian arsenals should be in a position to manufacture their own guns in case of urgent necessity when cut off by any exigency from free communication with England. These reasons were deemed so cogent that a committee of artillery officers was assembled to carry out experiments, with a view to making R.M.L. bronze guns for India service. They first attempted to utilize S.B. 9-pr. guns, but had to abandon the idea,‡ and subsequently 9-pr. R.M.L. cast at Woolwich gave such satisfactory results upon trial at Shoeburyness,§ that in 1870 9-pr. bronze guns were definitely adopted for Indian service,|| while some were also issued to batteries at home.¶

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* Thirty or forty of these bronze 8c guns accompanied the 3rd army.

† A detailed account of the committees and their opinions is to be found in pages 2-8-11 "Textbook of Rifled Ordnance." By Major Stoney and Captain Jones, Royal Artillery.

‡ The least weight of shell of suitable form which could be fired from such guns would have 20 lbs. Further, the great preponderance of the 9-pr. S.B. and the position of their trunnions, below the axis of the piece, presented obstacles to their conversion, while the metal of many of these guns was comparatively soft, and therefore less adapted for rifled guns.

§ These experimental guns were subjected to very severe trials. They were fired at the rate of 50 rounds in 7 minutes for rapidity; 5 rounds in 13 minutes at 9-ft. square target, at 1000 yards off, for rapidity and accuracy, giving 27 hits; and on one occasion 140 rounds were fired from one gun, without stopping, at the rate of 3 rounds per minute, the metal becoming so hot as to boil water placed in the bore. In all cases the results were satisfactory, and one of the guns in question actually fired 2,732 rounds without destructive injury.

|| In 1865 some mountain guns being suddenly required for Bhootan, a few old bronze S.B. 3-prs. were converted into 7-pr. R. guns, and since then a few more have been made, but their manufacture ceased in 1870.

¶ It must not be supposed, however, that this committee was altogether satisfied with ordinary bronze; on the contrary, they mentioned several methods by which it might be probably much improved, as mentioned in Note I. at the end of this paper.

As was the case with Prussia, we soon discovered that, notwithstanding the excellent results given by some individual guns, bronze was so uncertain a material as to quality, that it could not be relied upon for rifled guns. Further service developed so many defects in these 9-prs. that they have now been withdrawn, and replaced by R.M.L. pieces, constructed of the materials originally used with our rifled field guns, viz., wrought iron and steel, materials which have proved thoroughly efficient for the purpose required.

Writing in 1856 concerning bronze as a material for cannon, Dr. Mallet says :—"It is astonishing to find that after five hundred years habitual use of this material, the military literature of Europe appears barren of a single series of systematized and accurate experiments on the physical properties of gun-metal.* Nor has America produced such, although in advance by the skill and energy devoted to the improvement of its ordnance which its numerous government reports display.† Such an enquiry remains still to reward the labour and well directed knowledge that shall be bestowed upon it, and should gun-metal always continue to form the staple material for field Artillery (which however appears by no means probable) it would be an object worthy of national undertaking, an expenditure as being utterly beyond the reach of private effort or the demands of commerce."

Since 1856, however, much attention has been paid by scientific investigators to the improvement of bronze, and many attempts have been made to improve its quality both in hardness and homogeneity, by altering the proportions of the constituents and by adding small portions of other metals or non metals. None of these attempts have as yet proved satisfactory, unless bronze steel turn out an exception.

Phosphor-bronze containing small quantities of phosphorus has been extensively tried and given a metal of more uniform character and also stronger than bronze.‡

Experiments carried on lately in Belgium and at Tegel in Prussia with this alloy induced the latter power to give it further trial. A B.L. 9c (3·5) with charge of 1·5-lb. of powder and 18 lbs. shot was tested to destruction by gradually reducing its thickness after each series of firings and the result proved that there was no danger with phosphor bronze of a gun bursting without previous notice, while the metal is both harder and more elastic than common bronze. The Prussian authorities have ordered two 6-pr. and a 24-pr. of this metal to be cast at Spandau for testing it still further.

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* By the term "gun-metal" is meant an alloy of copper with tin, containing from 8 to 12 parts of the latter to 100 of the former, but in America we find this word also applied to cast iron of certain qualities.

† The annual reports prepared by the Bureau of ordnance and presented to Congress are worth study by artillery officers, being carefully condensed summaries of the latest experimental researches in America, and remarkable for their completeness.

‡ This alloy is much used now for bearings in machinery and is on trial for pipe boxes of field carriages, sheaves for blocks, &c.

Belgium however does not consider it worth while trying more experiments with phosphor-bronze.

In 1872 an exhaustive trial was undertaken at Bourges by the French Government with 4-prs.; four of these pieces were cast, two being of ordinary bronze and two of an alloy of phosphor-bronze, proposed by M. Montefiore Levy, one of the latter being cast solid and the other hollow. That cast solid failed at the preliminary water test, but the other stood well the first 500 service rounds and subsequently burst (but not explosively) with a charge of 4 lbs. of powder and a 20 lb. shot. Its superiority over the gun cast from ordinary bronze was so slight, that the committee carrying on the experiments, concluded that any advantages it possessed were more than neutralized by the necessity of adding the phosphorus in very exact proportions, and so further complicating the manufacture of bronze guns.

Colonel Rosset, of the Italian Artillery, superintendent of the arsenal at Turin, has for some years past been carrying on a series of interesting trials, with regard to bronze and other metals in the arsenal at Turin, where a 7·5c gun of bronze phosphorus was tested in comparison with others of ordinary bronze, This gun stood the trial well, and the alloy from which it was cast, (in an iron mould) showed a tensile strength of about 25 tons per square inch. Notwithstanding this, however, Colonel Rosset concluded that it was not advisable to employ such an alloy in gun manufacture on account of the unstable character of phosphorus, and the great difficulty of securing uniformity of result in the mixture of this element with bronze.

Russia appears to have adopted this nature of bronze for 3-pr. mountain guns, and is also trying it for for 9c R.B.L. pieces.

In Austria great attention has always been paid to bronze and analogous alloys,* and General Von Uchatius, the director of the Arsenal at Vienna, has for years studied the subject. In a lecture lately delivered by him, he tells us that about two years ago his attention was particularly called to a fragment of bronze, cast under pressure, which the Archduke William had brought from Russia. He found the properties of this metal so far superior to those of bronze cast in the ordinary way,† that he was led to the researches detailed in the following pages.

The experiments were begun by casting an alloy with 10°/₀ of tin, in an iron mould, under a pressure of 78 tons per square inch. The metal so obtained was homogeneous, and in quality resembled the Russian bronze.

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* "Sterro-metal" for instance was an Austrian invention, being a species of brass having in it small quantities of iron and tin; much was hoped from this when introduced in 1873. Its tensile strength is nearly double that of bronze, but it is difficult to secure uniformity in the casting.

† Ordinary bronze has a tensile strength of about 14½ tons, but bronze cast under pressure gives a tensile strength of 19½ tons, with an equal elasticity to common bronze.

A gun was about to be made of this compressed bronze, when the Exhibition of Vienna took place, and amongst the war materiel there displayed, was to be seen a bronze gun, cast by M. Laveissiére, of Paris, in a thick cast iron mould, so as to be cooled very rapidly; the longitudinal section of this gun, showed a homogeneous metal quite free from the spots, while the tests applied to specimens by General Morin, left no doubt as to the great strength of the metal, which seemed to resemble very much in its qualities the compressed bronze before mentioned.

This mode of manufacture, by casting in chill, being simpler than that of casting under pressure, it was resolved to adopt it in further experiment, and in August, 1873, a mass of bronze representing the breech end of a field gun was cast in an iron mould, five inches thick.* The bronze solidified in about 5 minutes, contracting considerably, so as to leave a hollow in the middle of the casting.

From the lower and more solid portion of the cylinder a disc was cut which showed towards the outer circumference, where the cooling had been most rapid, beautiful golden hued crystals, with their axes lying in a direction perpendicular to the surface of the cylinder, these crystals extended to a distance of 1·6 inches from the circumference, and gradually passed into a grey mass of very fine grains, which formed the central portion of the cylinder.† The properties of this crystalline portion are shown in table A. in the column headed "Bronze cooled in metal mould;" they resemble the properties of bronze, cast under pressure and of the Laveissiére bronze.

A great step had thus been taken in bronze manufacture, for this chilled bronze far surpassed that made in the common way in tenacity, though it had little advantage in elasticity and none at all in hardness.‡

A piece of this chilled bronze was next forged cold by rolling, considerable force was required, but the bar tested was extended by 100°/₀, or to double its original length, without showing the least fissure. When lengthened only 20°/₀ by the same process, the properties of this metal changed wonderfully, and it presented the same strength, hardness and elasticity as steel.—*Vide* table A.

Column headed, "bronze (cast in chill), rolled.§"

This then is the metal to which General Von Uchatius has given the name of "*bronze steel.*" It will be seen how appropriate a name this is, when we consider the latest definition of steel itself, viz :—"Any alloy or variety of iron, cast when in a melted state, into a *malleable* ingot."

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* The bronze contained 10°/₀ of tin; the dimensions of the mould were 28 inches in height and 10 inches in diameter

† This is more or less a characteristic of all bronze castings, the interior being always richer in tin, and presenting a different crystalline fracture from the exterior.

‡ This property was tested by the depth of indent made by a knife, under a given stated pressure.

§ The tensile strength of the metal was now 32 tons per square inch, and its limit of elasticity 11 tons. The tensile strength of Firth's steel used in our own gun building is about 30 tons untempered, (about 50 tons when tempered), and its elastic limit about 13 tons, while as shown by table A. Krupp's gun steel has a tensile strength of over 30 tons, and an elastic limit of about 6 tons.

To show the steel-like characteristics of bronze steel, knife blades were made from it, which exhibited all the properties of un-tempered steel.

If it were found practicable to construct a gun of chilled bronze thus steeled as it were by pressure or forging, General Von Uchatius considered that he had gained his great object, and provided Austria with a gun metal which would render her independent of foreign manufacture.

Before attempting the actual construction of a bronze steel gun, however, it was necessary to find out what were the proportions of tin and copper best suited for chill casting, and further how it was possible to give to the inner layers or walls of the bore, the same properties as those possessed by the outer layers of the casting.*

With regard to the first point, trials made upon a small scale proved that bronze containing 6, 8, or 10 per cent of tin answered well for the manufacture of bronze-steel, and that the addition of zinc offered no advantages. Further experiments on a larger scale also showed that 8 per cent gave the best results, and that proportion was therefore employed for the experimental guns; this alloy is more readily chilled than that which contains 10 per cent, while over that having 6 per cent it has the advantage of requiring less new copper when recast.

Regarding the second point it was clear that to obtain for the walls of the bore or inner layers qualities similar to those of the outer layers, it would be neccessary to chill them also by means of a core of some description. Hollow cores cooled by air or water, were first tried and unsuccessfully, but at length a solid core of hammered copper was found to answer satisfactorily.†

Having ascertained the proper alloy to use and the mode of chill casting to employ, the next step was to investigate the method by which the gun block, when cast, should be treated mechanically to ensure sufficient hardness and elasticity in the walls of the bore.

From his own study of the properties of metals and from the data furnished by tests carried on in Austria and other countries, General Von Uchatius had previously arrived at the following conclusions, viz.:—

1. That wrought iron, steel, and the ductile metals generally, when they have been extended beyond their original elastic limit, and so undergone a permanent change of form, have the property of acquiring a second and higher limit of elasticity.‡

2. Also that the work usually done upon the bore of a gun when first fired to the detriment of accurate shooting, especially the expansion of the powder-chamber, should be previously performed by means of a

* When a solid ingot was cast in an iron mould, having the thickness of the semi-diameter of the ingot, the interior portion of the latter was found to be composed of a greyish granular mass, unfit for forging.

† The details of these various attempts are full of interest, they are given in the Revue d'Artillerie Tome v. p. 310; and also the report of a serious accident on one occasion which caused the employment of water for cooling the core to be laid aside as too dangerous.

‡ There is no doubt that a bar of metal strained beyond its elastic limit will if subjected to a greater pressure behave like a bar of an originally harder metal, for the molecules will have re-arranged themselves and the bar will have a higher limit of elasticity, while its ultimate tenacity may be increased, i.e., its ultimate strength to withstand rupture. The total work done to break such a bar will still, however, be about the same. This question will be found further discussed in Note II, at the end of paper.

force greater than the maximum powder pressure, to which it can at any time be subjected.*

Chilled bronze he found had an elastic limit of 2½ tons, with an elongation of 0.0004, while if the same metal had already undergone a permanent extension of ten times the latter amount, or 0,004, its new limit of elasticity became 10 tons, and it was capable of an elastic elongation of 0,00192.

As the calibre fixed upon for the new Austrian field piece is 87 m. m., it would, according to this experience be sufficient to expand the bore by four thousandths, *i.e.*—87m.m. × by 0.004 or about 0.348 m. m., in order to obtain a new limit and to quadruple the elastic strength of the gun.

To give this necessary expansion to the bore, conical mandrils of hardened steel, were driven through an ingot of bronze steel, cast hollow in chill, in the manner already explained.

Hydraulic pressure of about 15 tons to the square inch was employed for this purpose, and several mandrils increasing slightly in size were successively forced through the bore until it was increased from 80 m. m. in diameter to 87 m. m., an increase of 8.75 per cent.† During this operation the exterior of the ingot was also increased in diameter by about 2 per cent. At the close of the operation, the bore presented a surface polished like a mirror, and with a hardness equal to that of steel.

When the last mandril had been passed through, the elastic contraction of the bore was found to be 0.004 of its diameter, an important fact which, according to General d'Uchatius, showed that "all the concentric layers of the piece, were in a state of elastic tension, exerting from the exterior towards the interior, a pressure equal to that which the mandril exerted from the interior towards the exterior, the latter being at least 14.75 foot tons, as far as could be calculated."

As a proof that this tension extended even to the exterior layers; a very thin ring of metal was turned off the outside of a cylinder treated as above, and before the last element of this ring had been cut through, the ring sprang off the cylinder and its diameter immediately became smaller than that of the latter; a similar ring cut from the interior, dilated on the other hand, when the separation was complete, showing that the metal there was in a state of compression.‡

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* By this General Von Uchatius would appear to mean that any permanent expansion of the bore by firing, and so increased windage and bad shooting, should be prevented by previous mechanical treatment of a material otherwise too soft. It is a question whether extra strength is given to the inner layers by this treatment, or whether a part of their total tensile strength is not overcome (vide note II.) they become denser, however, and so stronger to resist abrasion, while the elastic limit is higher.

† Sir J. Whitworth compresses his steel with a pressure of as much as 20 tons per square inch, reducing the length of the ingot by about one-eighth.

‡ This is quite clear, nor can there be a doubt that as General Von Uchatius states "the successive strata of metal in the steel bronze gun, from within outwards, possess a relative diminishing strength, hardness and elasticity, which is precisely what is demanded by the objective; at the bore namely the metal is strongest, hardest and most elastic (*i.e.* does not stretch most, but requires the greater force to stretch it to its elastic limit,) and as these properties diminish the toughness (ductility) of the metal decreases."

Is this gain brought about, however, by a loss in the total strength of the cylinder against rupture from within?

The German critic, quoted in note II, says that it is so, that General Von Uchatius is working upon a false conception of the laws of elasticity and strength, and that technical science will never admit that it is preferable to employ an overstrained to a sound material.

When a piece made as described is fired, the bore will, according to General Von Uchatius, undergo a sudden expansion, and immediately return to its original dimensions, provided this expansion does not exceed $\frac{4}{1000}$ of its diameter, as a spring rebounds unless stretched beyond its endurance. Should the tension of the gas be so great as to cause a greater dilatation of the bore than $\frac{4}{1000}$ of its diameter, then the elasticity of the metal being exceeded, the bore would become permanently expanded. Such permanent expansion could only take place if the pressure produced on explosion surpassed that which the mandril driven through it exerted on the walls of the bore during manufacture; *i.e.*, the pressure of the powder gas must be more than 14·75 tons per square inch, a pressure not likely to occur in field guns.

General Von Uchatius therefore considered that a gun made of steel bronze, as proposed, would be capable of fulfilling the conditions required of a field gun—*i.e.*, that it would be able with the normal charge to stand a great number of rounds, without any detriment to its accuracy; and further, that if it should, by accident, be submitted to a very excessive strain, it would not burst explosively, on account of the extreme ductility of the outer layers.

He states the following as some of the advantages of such pieces:—

That they would compare well with those made of steel in the ordinary way,* having the same hardness and homogeneity, and being submitted in manufacture to a greater pressure from within that which the powder gas can exercise.

In guns made of bronze steel, the properties of the metal in the several concentric layers differ in such a manner that while hardness, density, elasticity,† and tensile strength diminish from the interior to the exterior, the ductility of the metal (measured by the amount by which it will elongate prior to fracture) increases, and is at a maximum at the exterior surface.‡

In these pieces every concentric layer of metal performs its proper amount of work, and gives its proportional support to the walls of the bore, the "neutral" layer, or that layer in which equilibrium exists between the compression of the inner portions and the tension of the outer, is close to the surface of the bore, instead of being near the exterior of the steel barrel, as in built-up guns.§

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* Probably steel might be treated in a similar manner, and improve also in the properties mentioned as shown by Table B, the result of other experiments, by Gen. Von Uchatius.

† That is to say its "limit of elasticity," as defined by us, and measured by the greatest statical pressure which can be applied to a bar of a square inch section without producing permanent change of form. This is the same limit defined by Colonel Rosset, and rather more truly, as the "limit of cohesion," or that limit at which permanent change of form *rapidly* and *definitely* takes place, for long before that limit a small and gradual permanent deformation will have been caused.

‡ As will be seen by Table A the metal in the outer layer is 16 times as ductile as that of the inner layer. The ductility of good wrought iron of 27 tons tensile strength has been found to allow of an elongation of 0·38, while bronze steel from the exterior layer with 21 tons tensile strength shows a ductility of 0·40.

§ We cannot allow that this is the case with our own guns, when we see that the steel tube is so much compressed in some cases by the shrinking on of the outer portions, that the diameter of its bore is sensibly diminished.

Before a bronze steel gun could burst, the outer layers would stretch 40o/o, so giving a safety like that obtained when over a somewhat brittle steel tube, we place a jacket of ductile wrought iron.

Atmospheric action so injurious to steel would affect bronze steel but little.

The cost of construction, not taking into consideration the value of the material, is stated to be as follows:—

Steel tube, Austrian Manufacture	Martin'sSteel...about	£100
	Crucible „ ... „	£120
Bronze steel tube ... ... „		£35

Not only would the cost be less, but the time necessary for manufacturing a gun would be much reduced, while as before mentioned, Austria could at once supply herself with the new field armament required.

We now see by what experiments General Von Uchatius, starting with certain data, arrived step by step at what he considers to be the proper alloy, method of casting and mode of subsequent treatment by which a gun may be made of bronze steel, which gun shall possess all the advantages as to hardness and strength, which to be gained by constructing it of steel, while it would be free from the danger of bursting explosively, and also be far cheaper, both as to material and manufacture.*

The results of his experience certainly promise well, but the crucial test of the correctness of his views must of course be the trial of guns so made, as compared with similar pieces of steel or other material. As yet we only have full details of the trial of one field gun, constructed of bronze steel in the manner described.

This piece is a 8·7c B.L. gun,† of the same weight as the service 8 bronze M.L. gun, *i.e.*, about 10 cwt. The B.L. apparatus consists of a single coin with Broadwell ring, which acted very well.‡

In 1874 over 2000 rounds were fired with service charges, viz., 3·3 lbs. of a large grained powder, and a shell weighing 14·37 lbs. ;§ a muzzle velocity of 1475 f.s. being obtained.|| Since that it has been still further tested, so that up to April 1875, more than 2558 rounds had been fired from this gun without its being rendered unserviceable, or showing any sensible diminution of accuracy of fire. Indeed, a series of firing after the 2558th round, gave most satisfactory results as to accuracy, the targets being at a distance of about 1650 yards, and the mean error being about 1·7 ft. vertically, and 2·8 ft. laterally.

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* It is calculated that on the whole the present guns could be transformed, at a cost of three-fourths of the sum required for the supply of new steel pieces.

† The physical properties of the metal composing this gun are given in Table A.

‡ Four rings had to be used successively during the firing of the 2558 rounds; the first stood 647 fires, the second 1005, and the third 673.

§ Rotation being given by 4 copper rings, secured in undercut grooves round the shell, which rings are cut into by the lands.

|| Under similar circumstances and to the similar charges and the same powder, the steel 8·7c B.L. gun tried gave a muzzle velocity of 1498 f.s.

After each series of 200 rounds the bore was carefully examined and its dimensions taken. At the termination of the first 200, the bore about the middle of its length had expanded very slightly (0″·036 about) whilst a few small flaws (from tin spots), of lenticular shape, had been developed in the powder chamber and at the commencement of the rifling. These flaws slightly increased up to 300th round, but from that to the 2000th they remained constant both in number and size.

The diameter of the powder chamber remained nearly the same, for though measurement showed an enlargement of (0·1 m. m.) 0.0039 inches; this was due merely to the depth of a flaw and not to a real expansion of the chamber.*

The committee carrying on these trials also tested a steel 8·7c B.L. gun of the same construction under similar conditions, and the following is a brief summary of their provisional report rendered in January, 1875, when 2147 rounds had been fired from the bronze steel, and 1196 from the steel gun.

1. "The bronze steel gun shows sufficient 'resistance' (as to hardness, tensile strength, &c.), since after 2147 rounds with service charges the bore shows no degradation of form while the increase in diameter is within admissable limits."

2. "The experiments prove that in accuracy of fire the bronze steel equals the steel gun. The doubts expressed prior to trial as to the inability of bronze, even when treated by the Uchatius process, to withstand the action of the gas at a high temperature without erosion were not without foundation. The erosions caused do not however seem to affect the accuracy of fire as was expected."

"At the 2121st round the committee caused a shell to be exploded in the bore of the bronze steel gun, by which almost all the lands were more or less injured. Notwithstanding this damage and the erosions caused by much fire, the accuracy of the piece was not diminished, and the committee do not, therefore, consider such erosions of much importance, unless occurring in the neighbourhood of the gas check in the breech-end of the powder-chamber. Tin spots in that part of the gun are readily discovered, and it is recommended that any gun showing such should be rejected."

"The committee believe that the remarkable results obtained in these experiments are due partly to the Uchatius mode of constructing bronze guns, and partly to the use of copper rings for giving rotation to the projectiles."

Since the date of this report the committee have resumed their experiments, and 800 rounds more have been fired from the bronze steel gun mentioned, making a total of 2947 without material injury to the piece. Ten other guns have been constructed of the same material, from two of which 1500 rounds a-piece have been fired without their being injured in the slightest degree (according to Austrian newspapers).

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* The mean expansions of chamber after firing above 2000 rounds, were steel gun 17, bronze steel 14 in 1000ths of a millimetre.

"These rounds," we are told, "were fired in a rapid succession, 150 being fired each day with such rapidity that the guns became heated to 167° and 212° F. and had to be cooled with damp cloths. Even the best Krupp guns are injured by such rapid firing (becoming permanently enlarged), but no such results were observed with the Uchatius guns."

It is expected that the Artillery Committee will send in their report next month (June, 1875), and that the Austrian War Office will finally decide in the autumn as to the material for the new field guns, whether it should be Krupp steel or Uchatius bronze steel.

The results obtained with these experimental guns seem to bear out the sanguine expectations of General Von Uchatius; but our own experience of the uncertain nature of bronze, so far as we know of that alloy, and of the delusive effects of experiments made with only one or two pieces,* make us pause before we can accept this success as proof sufficient, that "bronze steel" is in all respects adapted for the construction of field guns, even if the theoretical principles are correct upon which its subsequent treatment are based.

The same view of the case has been taken in Austria, and the trials ordered to be carried out with the Krupp 8·7c steel gun are still to be proceeded with.

We cannot but wait with interest for the account of further trials with the 10 bronze steel guns last made, especially as General Von Uchatius had determined before constructing them to make further experiments with reference to the mode of casting and chilling, in order to get rid altogether of tin spots. This he believed he would be able to accomplish, but whether such be the case or not, the scientific world owes to the gallant General a debt of gratitude for his careful researches into the treatment of bronze, crowned as they have been by a discovery of no small importance, viz.—that of a method of treatment by which the physical properties of this alloy may be improved upon, until they approximate to those of steel, so that the metal itself may well be termed bronze steel.

If bronze steel is not utilized for the art of war, we may be certain that it will find its place amongst the thousand materials required by the arts of peace, and that its discovery† will give an impetus and a direction to research, which will ensure further improvement in the physical treatment both of alloys and metals generally.

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* *Vide* p. 4. As to bronze 9-pr. tried at Shoeburyness.

† *Vide* Note I., p. 15.

TABLE A.

Results of Experiments upon Gun Metals.

Weight in Tons per square inch.	Cast iron from a 9-inch gun		Bronze. Common bronze from an 8-pr.		Bronze. Cast in chill. As cast		Bronze. Cast in chill. Rolled.		Wrought iron, (Styrian)		Steel from Krupp 6-pr. gun		Bronze steel from The bore		Bronze steel from The exterior		Remarks.
	Elongation in hundred-thousands of the length																
	Elastic	Permanent	Elastic	Permanent	Elastic	Permanent	Elastic	Permanent	Elastic	Permanent	Elastic	Permanent	Elastic	Permanent	Elastic	Permanent	
0·636	2	0	10	0	8	0	2	0	4	0	1	0	3	0	3	0	
1·272	10	0	15	0	15	0	7	0	9	0	3	0	5	0	14	0	
1·908	15	0	25	0	25	0	10	0	11	0	7	0	8	0	25	0	
2·544	22	0	35	0	40	0	22	0	14	0	12	0	14	0	35	0	
3·180	27	0	47	1	53	2	37	0	18	0	16	0	20	0	55	0	
3·816	33	0	56	4	62	4	50	0	22	0	20	0	26	0	65	0	
4·452	38	2	66	7	70	6	60	0	24	0	25	0	33	0	78	0	
5.888	47	4	77	11	79	8	73	0	27	0	30	0	40	0	86	3	
5·724	54	5	88	20	87	10	86	0	31	0	34	0	48	0	93	9	
6·360	61	6	101	32	100	13	96	0	35	0	39	3	54	0	103	12	
6·996	68	8	110	52	108	22	107	0	37	0	44	5	60	0	112	18	
7.632	76	10	120	96	115	47	117	0	40	2	50	7	66	0	129	26	
8·268	84	14	...	...	130	117	128	0	42	3	55	10	73	0	135	45	
8·904	92	19	...	...	150	327	139	0	45	4	60	14	80	0	160	125	
9·540	101	24	...	...	170	380	149	0	48	5	65	20	88	0	...	...	
10·176	110	30	...	...	192	441	159	0	52	6	71	31	96	0	...	...	
10·812	120	35	...	...	...	...	170	0	57	7	76	38	102	0	...	...	
11·448	130	50	...	...	...	...	179	2	62	8	81	48	110	0	...	...	
12·084	142	65	...	...	...	...	193	5	67	8	85	120	115	2	...	...	
12·720	157	81	...	...	...	...	205	8	72	9	90	252	121	3	...	...	
13·366	...	...	...	...	...	...	215	10	77	10	98	360	127	5	...	...	
13·992	...	...	...	...	...	...	222	12	82	12	110	586	134	7	...	...	
14·628	...	...	...	...	...	...	239	14	88	14	...	...	142	8	...	...	
15·264	...	...	...	...	...	...	252	18	93	16	...	...	152	10	...	...	
Tensile strength, tons per sq. inch.	$15\frac{1}{2}$		$14\frac{1}{2}$		$19\frac{1}{2}$		32		$29\frac{3}{4}$		$30\frac{1}{2}$		31		21		
Limit of tons, elasticity per sq. in.	3·8		2·6		2·6		11		7		5·8		$11\frac{1}{2}$		4·5		
Elongation in hundreds of length. Elastic	0·033		0·035		0·040		0·170		0·037		0·034		0·110		0·076		
Elongation in hundreds of length. At mnt. of rupt.	0·40		15·0		40·0		2·1		22·0		21·4		2·5		40·0		
Section at point of rupture	0.96		0·66		0·54		0·96		0·62		0·50		0·96		0·58		
Hardness in mm.*	10·2		12·5		12·5		10·2		10·5		10·5		10·5		12·0		

* This hardness was measured by the indentation made in the specimen by a knife with given statical pressure, so that the greater the indentation given the softer the metal will prove.

NOTE I.

It is not intended by using the word "discovery" in the foregoing paper, to lay down that chill casting bronze, or casting that metal under pressure, was for the first time thought of by General Von Uchatius;* but that he first of all has discovered a way of practically utilizing knowledge already existing upon the subject.

The two modes above mentioned of improving bronze, as well as the method of subsequent treatment by compression, have long ago been proposed, and in some cases partially carried; as for instance, in the compressing the interior of the bore of the bronze S.B. pieces by forcing in a conical mandril, which used to be practised at the Royal Arsenal, Woolwich.

We find in "Mallet's Construction of Artillery," written in 1856, that the author proposes, as he says,—"For the first time * * * Absolute chill-casting of bronze guns in naked and massive iron moulds * * * which would admit of an almost unlimited increase of statical pressure on the head of metal, and would facilitate the delicate process of casting bronze guns hollow upon slender loam cores * * This method of casting," he further says, "would also give great facility to cooling the gun by currents of air through the interior of the core if thought desirable."

We know also that the process of casting steel under pressure has been in vogue for some time and on a tolerably large scale.

Colonel Rosset, of the Italian Artillery, as before mentioned, has been carrying out experiments in the Arsenal, at Turin, with bronze and other metals. A 7·5c B.L. bronze gun, cast in an iron mould, gave such satisfactory results that he reported that this mode of casting should be adopted, not only as giving metal of much better quality, but also as being much more economical; the expense of constructing new moulds for each gun being done away with as well as other expenses.

Not only was the elasticity, homogeneity, and hardness of the metal thus much increased, but also its tensile strength was augmented by as much as 50°/₀.

The Committee on Field Artillery for India in 1870,—President, Major-General Eardley Wilmot, R.A.—were quite alive to the defects arising from the comparative softness of bronze, and suggested several methods of hardening the metal; either by condensing the driving sides of the grooves by pressure, hammering the gun-block externally or internally, and externally on a taper iron mandril, by casting under hydraulic pressure, or by adding other ingredients to the alloy.

Time did not then admit of experiments being carried out as proposed, and on the introduction of iron and steel guns, the subject lost most of its interest with us.

Further investigations have, however, been continued by a com-

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* General Von Uchatius is already well known as the inventor of the Uchatius process of steel manufacture which is now employed in England, by Mr. Williams. For description, *vide* Dr. Percy's "Metallurgy," p. 802. Edition, 1864.

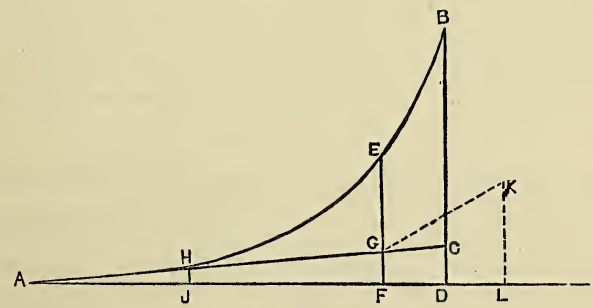
mittee,* charged to examine into the improvement of bronze for field guns, the report of which committee has just been published, and will be found full of most useful information as to the nature of bronze guns, and the causes of local defects. It is accompanied by various tables of chemical analyses of bronze, and details as to the different alloys, fracture, &c. Appended to the Report will also be found a précis of the lecture by General Von Uchatius, and a translation of a critique upon the lecture taken from the "Militärische Blâtter," which is treated of in the following NOTE II.

NOTE II.

In the preceding pages no attempt has been made to criticize the theoretical opinions expressed by General Von Uchatius, but as in his lectures he distinctly challenged comparison between a bronze-steel gun and a gun of Krupp steel, we may now examine what has been said on the other side against bronze steel theoretically, as a material for Ordnance. There hardly appears a doubt but that steel might be so improved as to be superior to bronze steel in every required quality under somewhat similar treatment. The practical point just at present, however, which Austria requires to know is, whether bronze steel can furnish her with a thoroughly efficient Field Ordnance, supplied from her own Arsenals, seeing that her capabilities of steel manufacture are not as yet sufficient to allow of her using that material without having recourse to other countries.

For ourselves this comparison has much scientific, though perhaps little practical interest, so we will take in succession the points of comparison between a steel bronze gun and a Krupp gun, as laid down by General Von Uchatius with his critics' remarks thereupon.

To avoid any misunderstanding as to technical terms, it will be advisable to state their meaning distinctly, and the following graphical illustration of the "limits of elasticity" and "fracture" of a metal extracted from the "Militärische Blátter will aid us in this very much:—



* President, Major-General Eardley Wilmot, R.A., F.R.S.; Members, Colonel Campbell, C.B., R.A., &c.; Professor Abel, F.R.S., &c.

In the above figure let the abscissæ represent the strains and the ordinates the total extensions of a bar of metal (experimentally determined) corresponding to the strains.

If the bar be subject to a constantly increasing strain the elongation is first constant in proportion to the strain,* increasing after a certain point in a higher proportion. This point, represented in the diagram by the extension of *HJ* and measured by the statical strain corresponding to the abscissa *AJ*, is termed the "limit of elasticity."†

After this point is reached the extensions increase in a higher proportion for every increment of strain and the line joining the ordinates becomes a curved line, as shown in the figure at *D*, the total extension of the bar at that point being represented by *BD* and the breaking strain by the abscissa *AD* which is the measure of the "limit of fracture."‡ We have then, as will be seen by the fig., three extensions of the bar, the "total," "elastic," and "permanent," the former being in all cases the sum of the two latter, while, until the "limit of elasticity" is reached, the total extension is synonymous with the "elastic" extension—(strictly not quite so but very nearly).

The curve (a straight line as far as *H*) *AB* represents the total extensions, and the straight line *AC* the elastic extensions of the bar, while the total mechanical force required to produce rupture corresponds to the area *ABD*.

Similarly the mechanical force necessary to produce a total extension *EF* corresponds to the area *AFE*.

If we remove the pressure represented by *AF*, after the bar has been elongated by *EF*, and then re-impose it, the greatest extension of the bar will not exceed *FG*‖; and if we once more remove the strain the bar will revert to its former length, *i.e.*, its original length + *EG*:

Here, of the total work done on the bar, represented by the area *AFE*, that portion corresponding to the area *HEG* has been absorbed by it and applied to the re-arrangement of its molecules, being the measure of the loss sustained in the *total tenacity* of the bar. Its breaking strain may however be increased, and we see that its elasticity is so, for any ductile metal increases (within certain limits) in elasticity and ultimate strength (as represented by the breaking strain), though not in absolute strength, (as shown by total work or mechanical force required to produce rupture) when subjected to drawing, hammering, or rolling. In fact, a material strained beyond its limit of elasticity will exhibit the same characteristics as an original harder metal.

To return, however, to the case in the figure:—Suppose we now

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* This extension increases very slightly in proportion of the duration of the strain.

† By some, as before mentioned, termed the "limit of cohesion."

‡ This limit of fracture is often said to be a measure of the "tenacity" or "tensile strength" of a metal, but is in reality only a measure of the "ultimate" tenacity, or ultimate "tensile strength." *i.e.* the breaking strain, and does not represent the total strength of a given metal to withstand a strain, or in other words, the total mechanical force required to produce rupture.—*Vide* Mallet's explanation, "Construction of Artillery," p. 73.

‖ This, however, according to Mallet, p. 57, will not always be the case if we reimpose the weight for any time. With wrought-iron, for instance, should the strain exceed one-fourth the rupturing strain, the extension will slowly increase with time.

subject the bar, which has been elongated by the permanent extension *EG*, to a heavier pressure, then the total extensions may be represented by same line *GK*,* and we see that the "breaking strain," shown by *AL* is greater than before. The "total mechanical force" to produce rupture will now be represented by the area *AKL*, which, however, can never exceed the mechanical force represented by *ABL*, or which is the same thing *FGKL* cannot exceed *BDFE*, so that the *absolute strength* of the metal is not increased by permanent extension beyond its original "limit of elasticity," although its breaking strain and elasticity may be increased by the operation.

We must then remember that increase in the limits of fracture (or breaking strain) and elasticity do not imply greater working strength in a given bar of metal.

We do, however, gain very much, as we all know, by subjecting metals to the operations of rolling, hammering, &c., for we obtain greater elasticity and ultimate tenacity in smaller bulk by making the mass more homogenous; and here seems to be the weak point of the critique in question, for although steel might undoubtedly be further improved, the question lies between the present ringed Krupp guns and those of bronze steel as now made.

The points of comparison *pro* and *con*, are as follows:—

1.—"In endurance the bronze steel gun can only be compared with the ringed steel gun, since internally they possess the same strength, homogeneity and hardness; while an elastic pressure is exerted primarily from without inwards, exceeding that exerted by the bursting effect of the powder."

Remark on above.—"The tension previous to firing, is in the bronze steel gun in exactly an opposite state to the tension in a Krupp ringed gun. Hence the two pieces admit of no comparison."

The criticism seems scarcely justified as it stands, for the tension of most of the layers of the bronze-steel gun, certainly of all the outer ones, is of the same character to that of the steel rings, although primarily induced in a different manner.

To give a simple example.—Suppose we take a roll of stiff paper, $\frac{3}{4}$-inch internal diameter, which requires some little force exerted from the interior, to expand it to an inch diameter, insert inside a pair of glove stretchers, and on the exterior place an india-rubber band just fitting over the roll of paper; expand the latter from the interior, till its diameter is one inch, by means of the stretchers, and we see that the whole thickness of the band will be in a state of tension, representing that of the exterior layers in the bronze steel gun.

The compression of the inner layer of compressible bronze steel cannot of course be simulated in this case.

Again, take a roll of similar paper, say an inch and a quarter external diameter, place over it a thin india-rubber ring, (say $\frac{1}{2}$-inch internal diameter) of not sufficient strength to compress the paper roll more

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* If the metal were perfectly homogeneous, *LK* would correspond with *BD*; but as most metals are in a state of internal tension, which is nullified by pressure beyond their limit of elasticity, the limit of fracture may frequently be thus increased.

than $\frac{1}{4}$-inch, it is evident that all the layers of the india-rubber band will also be in a state of similar tension to that of the band in the first case, though induced in a different manner. In this second case the expansion of the interior diameter of band and its state of tension is induced by the resistance of the paper tube to compression beyond a certain amount, and by the inability of the band in consequence, to return to its normal state.

The expansion of the band in this case represents the expansion by heat of the rings in actual manufacture, and their being subsequently prevented from re-assuming their original diameter, while in the first case the expansion of the paper roll with the ring upon it, is similar to the mode in which tension is given to the outer layers in the bronze steel gun.

It must be confessed, however, that in one case the power of the paper roll, or inner layer itself, to resist expansion from either is weakened, while in the other case (that of the ringed gun) it is on the contrary increased.

Is this defect counterbalanced by the different layers in the bronze steel representing infinitely thin hoops in different states of tension?* This brings us to the next condition, viz.,—

2.—"The successive strata of metal in the bronze steel gun from within outwards, possess a relatively diminishing strength, hardness, and elasticity, which is precisely what is demanded by the objective; at the bore, namely, the metal is strongest, hardest, and most elastic, and as these properties diminish the toughness of the metal increases. The elasticity of the bore and the toughness of the outer surface are greater than in steel."

Remark.—"The small malleability of steel bronze at the bore reduces the power of resistance (mechanical fracturing force) to about $\frac{1}{8 \cdot 5}$ of Krupp steel;† the toughness of the outer strata cannot compensate for the hardness of the inner strata."

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* Each tube or hoop, when of a definite thickness taken by itself, has an element of weakness, its inner circumference is more stretched and strained than its outer circumference. Absolute perfection would necessitate infinitely their hoops, and practically the thinner the layers the greater the strength, provided the mechanical difficulties in constructing, and more especially in applying a great number of their strata with the proper tension do not outweigh their advantages.—"Holley on Ordnance," p. 245.

This disadvantage, as well as that of want of continuity, are got over in the bronze steel gun. Defects fully explained by Dr. Longridge, in "Construction of Artillery," and which he endeavonred to surmount by winding steel wire round an inner tube, the several layers being put on with different degrees of tensions. The system of construction is now being tried in France with much success, it is said, in the case of an experimental field gun.

† The total mechanical force necessary to break a bar, depends principally upon the expansion at the limit of fracture. (*vide* fig. p. 16), and the tougher the gun metal the safer the gun; but on this point his critic observes, that the Krupp steel with 21·4 per cent. extension (*vide* Table A) is tougher than the bronze steel of General Von Uchatius with 2.5 per cent.—"Unfortunately," he says, "the Table (A) does not go far beyond the "limits of elasticity, and it is not easy, therefore, to arrive at the total mechanical force "necessary for rupture. Experiments carried on by Kirkaldy, in London, show that this "force is with Krupp steel, 142·5k per cm., as compared to 9·88k in the case of common "bronze. We may therefore say, that with Krupp steel and bronze steel, these forces "would be 171·2k per cm. and 20·31k per cm. respectively," *i.e.* 8·5 : 1.

Whether the exact proportionate strength mentioned by the critic be correct or not, it is evident that he is right in saying that the strength of the inner layers of the bronze steel, taken "per se.," is much less than that of the inner layers of a Krupp gun; a part of the work towards the limit of fracture having already been performed upon them. Still, if they be much better supported by all the layers outside them, they may be quite strong enough for the purpose required, as compared with a Krupp gun, the stronger inner tube of which may not be so well supported.*

As to the toughness of the outer strata, not compensating for the small expansion of the inner layers before fracture, and so not ensuring safety against explosive rupture under an excessive strain; this seems a doubtful point, which can only well be determined by experiment.

3.—"The elastic tension exerted primarily from without inwards against the bursting effect of the powder, is continuous through all the strata of the metal. The neutral stratum, where the inward and outward pressures are balanced, is situated quite close to the bore.

"The elasticity of the whole thickness of the wall must be overcome simultaneously as well as lastly, the enormous toughness of the outer strata, which may be subjected to an extension of 40°/₀ without tearing before the gun will burst.

"In the ringed steel gun the neutral stratum is situated at the contact of the barrel and the rings, and the force of the explosion falls almost entirely on the rings. The gun will hold out, provided the limit of elasticity of the rings is not exceeded; but should an excessive strain cause one ring to fly, the other parts of the gun will, in all probability, follow."

Remark.—"The expansion of the individual strata of the barrel, arising from the driving through of the cones, seems to correspond to the laws of elasticity laid down by Lowè. The ringed steel gun is so constructed that the barrel previous to firing is compressed to a certain fixed degree, while the rings are in a state of expansion; thus on firing the limits of elasticity in the strata of both barrel and rings are reached simultaneously.

"Again, since the tenacity of the barrel at the limit of elasticity is greater than the force of the powder gas, the rings are virtually less affected than the barrel, and not *vice versâ*, as the General would lead one to believe."

Here the General and his critic seem to agree, save on the question as to when and to what extent the strength of the rings of a Krupp gun is called upon when the powder-charge is exploded.

This is a matter of adjustment depending on the limit of elasticity of the barrel, that of the successive coils or rings when shrunk on, and on the amount of compression given to the inner barrel. No doubt if this adjustment is perfect the limits of elasticity of all might be reached simultaneously, but then comes the dangerous point in steel. What amount of expansion have the outer rings beyond the limit of elasticity? for upon this depends greatly the safety against explosive bursting, a

* *Vide* Note on previous page.

safety so notorious in the case of our iron-bound guns, in which the expansion of the outer layers of wrought-iron is considerable after the limit of elasticity is past.

Should the adjustment mentioned not always be perfect, as is probably the case, considering manufacturing difficulties, and the varying nature of steel, we have an unpleasant doubt as to the safety of a Krupp gun exposed to any excessive strain.

4.—"The scoring of the barrel is a purely mechanical work in which chemical action plays no part. Experience shows that brittle metals, or hard places in bronze guns, are most liable to scoring. The vent must consequently be made of the softest copper.

Just as the sand blast* spares soft and attacks hard substances, so the powder-gas in a high state of tension and mixed with unconsumed powder, escaping by a narrow opening, eats first into the hardest spots it encounters. This accounted always for the proneness to scoring of the old bronze guns.† The new guns will have no tin spots, and the metal is not brittle; they will not, therefore, be more liable to scoring than steel guns.

Remarks.—"We can only answer that in the first place, the General has not yet succeeded in casting the metal without tin spots, while, if his theory is correct, that 'hard places in bronze guns are more liable scoring,' it follows that the bronze steel gun must be more liable to this defect than a gun of ordinary and well-cast bronze, since the former metal is much harder."

As to this condition his critic seem to have the best of the argument, for General Von Uchatius indulges in prophecy when he states, that his new guns will have no tin spots.

As to the other point, he may perhaps maintain, that some of the old tin spots containing "putty powder," were even harder thanbronze steel, while he can scarcely be wrong in stating, that "they will not be more liable to scoring than steel guns."

Upon the wide question of the physical properties of metals, his critic is rather hard upon General Von Uchatius, stating that he "arrives at the extraordinary conclusion that the tougher metals attain their maximum capabilities when strained beyond their limits of elasticity, *i.e.*, when permanently extended." Also further on, "he is working upon a false conception of elasticity and strength," *i.e.*, in maintaining that a bar so strained attains an "increased tenacity." All this seems based upon a mistake as to the terms used. For General Von Uchatius does not appear to imply that the total strength of a metal is so increased, but only that its breaking strain is increased, and that bronze thus treated attain its maximum capability for his

* This refers to an American invention in which a strong blast of air, or steam carrying sand with it, is directed upon a sheet of glass which has previously been coated with some yielding substance, except where it is desired to cut a pattern—the hard uncovered portions are quickly eaten away by the sand driven against them while the yielding surface remain uninjured.

† The tin spots, though more readily acted on by heat, are harder than bronze.

particular purpose, not necessarily that it becomes really stronger on the whole.

To sum up, however, and to criticize both the General and his critic, the following seem to be fairly safe conclusions to arrive at. Should bronze steel be obtained quite free from tin spots, should its production prove of uniform quality, and should a gun constructed of that metal when tested to destruction, show safety against explosive bursting by the extension of the tough outer layers, after fracture of the inner layers by excessive strain, then this material may prove to be that required by Austria at the present moment, both on account of the economy, ease and rapidity of manufacture, and also especially as making her independent of other countries in the construction of a new field armament.

It seems unlikely, however, that such a metal can long hold its own against the great improvements certain to take place in steel manufacture, and in the construction of field guns from that material on sound theoretical principles.

Still, time presses, and while the political horizon is so dark nations cannot always wait for the consummation of improvements. It is necessary that their Artillery should be as good as that of their neighbours.*

If bronze steel guns can be made of equal power to those of the new Prussian field pieces, it may be good policy on the part of Austria to supply herself at once with a field armament of bronze steel, and then with an easy mind await the further development of her steel† manufacture.‡ Whether this be the the case or not, Austria will owe to General Von Uchatius, a discovery arrived at by philosophical experiment and practical skill, which stamp him as a scientific artilleryman, in whose success we, of the British Artillery, cannot but feel a brotherly interest.

Postscript.—To drop the "we" and revert to the more modest pronoun. Though I stated at the commencement of the paper that no apology was required for the production of the paper itself, I yet feel that with regard to the few individual opinions expressed in Note II., I must disclaim any idea of supposing them to be authoritative, knowing, as I do, how complicated a problem gun construction is, how many variables have to be considered, and how little I have myself studied the subject. Many of my readers have entered into it far more deeply than I have done, and to them I would say,—"As you are strong, so be merciful."

J. F. O.

Woolwich, May, 1875.

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* Since the above was written, we are told by the Austrian correspondent of the "Standard,"—"That the introduction of the steel-bronze cannon has been definitely settled upon, after long and furious journalistic struggles,"—and "that the Committee have voted for their adoption by 27 votes against 1." It seems improbable, however, that the Austrian War Minister should yet have made his final decision.

† By steel is here meant, as before mentioned, "any variety of iron cast when in a molten state into a malleable ingot."

‡ As France has done in the case of her Reffye guns.

ON CENTRALISATION,

AS APPLIED TO THE

MANUFACTURE OF WAR MATÉRIEL.

BY

CAPTAIN C. C. SAXTON, R.A.

[THE R.A. INSTITUTION PRIZE ESSAY OF 1875.]

"Si vis pacem, para bellum."

"Although it may be a bold design to write upon such a subject, yet I do not consider it blameable to warn people by a mere dissertation, when others have made bold enough to do so by their actions; for the mistakes which I may commit in the execution of this project can easily be rectified without harming anyone, whereas in the practice and execution of warlike operations, if a mistake be made, it can but be to the prejudice of a state."—*Machiavelli.*

Definition of War Matériel.

War matériel comprises all that vast variety of warlike stores, arms, and equipments required by both the army and navy, in order to maintain themselves in a proper state of efficiency, alike in time of peace and in time of war.

Under this head may be mentioned the following, as being principally important:—

Accoutrements.
Ammunition of all sorts.
Armes blanches (swords, &c.)
Cannon, for both land and sea service.
Carriages for ordnance, and for military transport.
Clothing.
Gunpowder, and its means of ignition.
Harness and saddlery.
Rockets, torpedoes, and all compositions employed for warlike purposes.
Shoes.
Tents.
Tools.
Small-arms.

War matériel may also, with reference to the question of supply, further be classified in two great divisions, viz. :—

1. That which is required for purely military purposes.
2. That which appertains to naval warfare, and the service of ships.

Arsenals.

The manufacture of war matériel is usually carried on in establishments called arsenals, and these latter have been defined by competent authorities to consist of three classes.

1*st Class.*—First-class arsenals are those which, in addition to providing for its repair and storage, are also charged with the manufacture of war matériel in the first instance.

2*nd Class.*—Second-class arsenals are those in which large stores of war matériel are kept, together with the necessary workshops for the repair of all warlike stores with which they may have to deal, and such facilities of expansion as may enable them, in case of necessity, even to carry on their manufacture to a limited extent.

3*rd Class.*—Third-class arsenals are employed for the purposes of storage and distribution alone, and are in fact mere depôts of supply.

It is, therefore, with the two first of the above-mentioned classes that we shall principally have to deal in the following pages.

The chief points which have to be considered in the selection of a locality wherein to seat the manufactures of war matériel of a state, are briefly as follows :—

1. Strategical considerations.
2. The presence of the raw material on the spot, or in its immediate vicinity.
3. Facilities for its manufacture into the finished state.
4. Ample means of distribution to the consumers.

Of the above, the first is no doubt the most essential and important, and may be considered as the discussion of the question of the manufacture of war matériel from a purely military point of view. The three latter points, on the other hand, may be considered to represent the exigencies of the question from an entirely civil stand-point. From this latter, we must regard the manufacture of war matériel in much the same light as any ordinary operation of trade, and as being equally governed by the same, or similar, laws of supply and demand. We therefore propose discussing the subject of this essay under the above different heads, premising by observing that, although we may not succeed in uniting all the above conditions in one spot, yet we may so succeed in combining several of them at different points as to counterbalance, or even exceed, the much vaunted advantages of unity and concentration.

Strategical Considerations.

The strategical considerations with reference to the choice of positions for manufactories of war matérial depend upon—

1. The attitude of the nation—whether defensive or offensive.
2. The position of the capital.
3. The strategic points occupied by the army.

Defensive.—If a nation be standing upon the defensive, its arsenals should be fixed in some central situation in the interior of the country, so as to be as far as possible removed from the attacks of the enemy. The works covering such a central arsenal would form, as it were, a *reduit* for the remainder of the country. It would be in this direction that an army beaten in the first encounters upon the frontier would direct its retreat. It would form a rallying point for the reserves assembling from all parts of the country, and would become, as it were, a perennial source from which fresh armies would spring to meet the enemy, as long as the stronghold remained unreduced. Under cover of its fortifications a defeated army could be rallied and re-organised, while its ample stores would afford the means of re-equipment for the field. Such a place of arms should, in the words of Colonel Hamley, "contain sufficient material for a great army in artillery, fire-arms, provisions of all kinds, workshops, arsenals, hospitals; in fact, collecting all the raw material which naturally flows from the surrounding district into a great city, should be capable of converting it, by means of a large population of artisans and of extensive manufactories, into the material of war—of turning brass into cannon, iron into projectiles and rifles, wood into trains of wagons, wheat into biscuit, canvas into tents, &c.—so that an army might manœuvre round such a place, either in its own or the enemy's country, secure of all the support which a near base can afford."

Offensive.—For the offensive, such great arsenals and entrenched camps may be situated within easy reach of the frontier which divides the state from the theatre of war. Supposing everything to turn out well in the plan of an offensive campaign, such a situation no doubt becomes advantageous in the extreme. The invading army possesses a secure base at the smallest possible distance in its rear, and the time for the transport of supplies of all kinds to the front is reduced to a minimum. Victorious, the invading army is supplied in the safest and most expeditious manner; if compelled to retreat, the army falls back upon its place of arms, and manœuvring around its entrenched camp, bars the passage of the frontier to the enemy. But then, what nation can always count upon being able to assume the offensive? A nation which, having reckoned upon its own ability to always assume the offensive, finds itself suddenly, in its own turn, assailed, may find that the selection of such a situation for its manufactures of war matériel as we have above supposed is attended by the most fatal results. We have recently seen the evils of the concentration of a number of manufactures of war matériel and stores within reach of the enemy exemplified in the case of Metz. In July, 1870—a short time before the Franco-

Prussian war broke out—the Emperor had issued a decree ordering the formation of a great central arsenal for France at Bourges; but, unfortunately, time was wanting to carry out the plan. As it was, Metz contained the principal arsenal, and the chief manufactories of war matériel in the whole country; and thus, all the vast resources and supplies which the place contained became useless from the moment of its investment. Of course, the investment of such a place of arms at once blocks up the channels of supply to the country, and the vast stores locked up in it become as useless for the defence of the state as if they were already actually in the hands of the enemy. Thus, although Metz and its resources did not fall into the hands of the Prussians for a considerable period, yet for all practical purposes they were lost to the French; and the latter were compelled to resort at once to foreign markets in order to provide the necessary war matériel for the new levies and reserves, with which they vainly endeavoured to stem the tide of invasion.

Another instance of a great arsenal and place of arms constructed for purely offensive purposes, is afforded by Sebastopol. Its sole *raison d'être* was the ultimate view of an attack upon Turkey; and when Russia, in her turn, became the object of attack on the part of the allied powers, the great development of the dockyards and arsenals of Sebastopol, combined with the accessibility of the place to the fleets and armies of the allies, rendered it a most prominent and tempting object for their efforts; while, at the same time, its distance from the capital, and the state of its communications with the centre of the empire, rendered its succour a difficult, costly, and finally an unsuccessful affair.

Archduke Charles.

Speaking of fortresses and places of arms, both of an offensive and a defensive character, the Archduke Charles, in his "Principes de la Grande Guerre," lays down as follows:—"For fortresses which are destined to serve as a support to offensive operations, one must principally take into consideration the points from which an offensive war can and ought to be carried out against the enemy; that is to say, the chief avenues to his country, and the communications with the same. They should contain important magazines, and be so situated that, in case of disaster, they should cover the retreat of the army, and hinder the progress of the enemy. They ought, consequently, to be of considerable size. There is a third species of fortresses, which are less for the defence of frontiers than for the safety and preservation of a whole country. These fortresses should be placed in the interior of the provinces, and are, properly speaking, places of arms. Their object is to preserve stores of all kinds for the maintenance and equipment of armies, to receive beaten troops, to favor their organisation and armament, and also to offer a rallying point for the military forces still existing in the provinces. But such fortresses must have a great *enceinte:* they should be situated at central points where the roads from the interior are met by those from the exterior, and whence communications extend to

the countries in rear; or else, *à cheval*, on navigable rivers, of which they should assure the communication from one bank to the other."

If we centralise our manufactures in fortresses of the description mentioned in the first portion of the above remarks, we are evidently acting on a wrong principle, as is apparent from the unfortunate example of Metz. Bourges, on the other hand, constitutes a good instance of the description of place of arms contemplated in the latter portion of the Archdukes remarks; and such a position would constitute an excellent site, strategically speaking, for the establishment of large manufactories of war matériel.

Position of the Capital.

The seizure of the capital of a nation by an enemy's army, is like arresting the action of the heart in the human body. It paralyzes the action of all the members, and, as a general rule, peace must be obtained at any price which the conquerors may choose to exact. Nevertheless, such a contingency need not be absolutely fatal, as long as armies continue to remain in the field, and possess the means of organising and equipping themselves for further conflict. On two occasions, after securing the Austrian capital, Napoleon had to beat their armies in the field, in order to crown the issue of the campaign; while his occupation of Moscow failed utterly in bringing the Russians to terms. Nothing can be easier than to paralyze the military forces of a weak power, or even of a great one, by seizing upon its main sources of supply of war matériel. Unless it should be enabled to obtain the necessary supplies by purchase from abroad, it is simply deprived of all means of further resistance, and must inevitably submit to whatever terms the invader may think fit to impose. The seizure of the capital of a state may, to a certain extent, paralyze the action of a Government; but the possession of its main arsenal and manufactures of war matériel grasps the source of its absolute force by the throat, and renders further resistance hopeless. At the present day it would almost appear to be of greater importance to obtain possession of the main arsenals than even of the capital itself. This being the case, nothing can be more unadvisable than to have the main arsenal and the capital lying immediately adjacent to one another—unless, indeed, it were possible to have them so strongly fortified as for one to assist in the defence of the other. But even granting this, there is a homely proverb which teaches us that we should not place all our eggs in the same basket, and so risk losing all our fortune at one fell swoop, owing to some untoward accident which it would be impossible to have foreseen. Dangers which can be foreseen can be provided against; but it is only by removing, as far as our power extends, the mere possibility of accident, that we can guard ourselves against the unforeseen, which is ever the most dangerous element in war. When the main arsenal and the capital of a country lie widely apart, it becomes a grave question for a Government acting on the offensive to choose their object of attack. They may choose either to strike at the political centre of the country by moving on the capital, or they may prefer to direct the action of the invading army

upon its military centre—that is to say, its main arsenal and the seat of its manufactories of war matériel. When, however, both of these objective points not only lie close together, but are also unfortified into the bargain, no room can remain for hesitation. Such a combination presents the example of two prizes of unequalled magnitude, which may both be won by a single cast of the die. From the above considerations, therefore, it would appear that the main arsenal—if such it is to be—should be established well in the interior of the country, at some great strategic centre tolerably remote from the capital, and there fortified with all the art that engineering skill and science can command. Nor should the main arsenal only be fortified in itself, but it should also be further protected by other fortified places in the vicinity.

The Strategic Points occupied by the Army.

The situation occupied by a main arsenal should evidently not only be a great strategic centre itself, always containing a considerable amount of troops, but should also possess easy communications radiating in every direction towards other strategic points permanently occupied by the army. These communications form at once the channels of supply for the depôts established at the various district head-quarters, and at the same time afford the means of rapidly pouring the troops from other parts of the country into the common reservoir of the entrenched camp surrounding the place of arms. Since we have already inaugurated a system of decentralisation as regards men, by the localisation of the forces and the establishment of depôt centres, it would appear to be only a logical result of our military policy that a similar decentralisation with regard to war matériel should soon take place. Since, in principle, each tactical unit should be prepared to take the field direct from its own head-quarters, it is evident that the depôt centres should comprise depôts of supply sufficient for the provision of at any rate arms, clothing, tents, and camp equipage. These depôts would, however, be merely supplementary to those established at important strategic points in the various military districts. These latter should be, at any rate, second-class arsenals, but how far they should be charged with the *manufacture* of war matériel remains to be considered.

Presence of Raw Material.

One of the chief considerations which usually govern the establishment of manufactories of the ordinary commodities of commerce, and which, strategy apart, we conceive to be to a great extent applicable to that of those intended for the manufacture of warlike stores, is the presence of the raw material. Great manufactories of ordinary articles are usually established in localities producing the crude material, and these, in the course of time, become great centres of industry, attracting within their sphere large populations of skilled artisans and of miscellaneous labourers of all kinds. In the first instance, the presence of coal and iron has generally been the motive for the commencement of our principal manufacturing industries; and the labouring population,

attracted to these, have at length arrived at such dimensions as to form great towns and cities which, in case of invasion, would demand protection. Thus we are brought to the conclusion that, in selecting a site for the establishment of manufactures of war matériel, one of the first requisites is the presence on the spot, or at any rate in its immediate vicinity, of the raw material, in the shape of coal and iron. A place of arms so situated would further possess the advantages of deriving protection from the fortified places in its vicinity; for these latter, being great centres of wealth and commercial activity, should not be left undefended.

Facilities for Manufacture.

Great facilities will be afforded for the manufacture of war matériel if the arsenals be placed in districts where skilled labour already exists in large quantities. In our manufacturing districts there exist whole populations of colliers, of iron-workers, of artisans, and of mechanics, of whom the two last-mentioned classes could be initiated with the utmost facility into the technicalities required for the special manufacture of war matériel. In most instances the growth of these industrial and manufacturing populations has been the work of many years. They have grown up *pari passu* with the extension of the various works and industries which first called them into existence. Any sudden cessation of manufacturing effort, owing either to strikes or war, has a most disastrous effect among many thousands of working hands. In the latter case, however, we may very largely avail ourselves of the skilled labour of the civil population in the manufacture of war matériel. In establishing, therefore, our manufactures of war matériel in the midst of an industrial population of mechanics and artisans, we not only provide ourselves with the means of obtaining an almost unlimited supply of skilled labour, but we possess facilities for keeping that skilled labour up to the standard of efficiency—which, owing to constant improvements in manufacture, is a necessity in both peace and war. We, moreover, possess the means of, to a certain extent, averting that widespread misery and destitution which would be produced among our industrial population by a war which should cause any great cessation of commercial enterprise and activity.

Distribution to Consumers.

With regard to the great industrial manufactories of general materials, it is the whole population of the country who are the consumers, and consequently they are generally found surrounded by a perfect network of roads, railways, and canals, radiating in every direction, and affording a ready means of distributing the manufactured merchandise throughout the country. In the case, however, of military manufactures of war matériel, it is the army alone which are the consumers; and therefore they should be situated in positions affording every facility of supply to depôts in the way of numerous and easy communications, both for outlet and ingress. There can be no doubt but that, within certain limits, decentralisation, both of manufacture and supply, is to the advantage of the

consumer. Thus, in the case of great commercial undertakings, when these latter have attained a certain development suited to the requirements of the surrounding district, the proprietors do not still further increase their establishments with a view of attracting customers to their business from more remote places. On the contrary, they proceed to decentralise, by establishing branches in other parts of the country, so as to tap fresh sources of consumption. In fact, it is a great principle of trade that you must bring the article within reach of the consumer in order to create a demand for it, and not attempt to attract the consumer to the article. It may not be uninstructive to draw a slight parallel between the manufacture of ordinary articles and that of war matériel. In the first, the three elements are the proprietors, the people employed in the undertaking, and the consumers, who are the general public; in the second, it is the state which is the owner, and which derives the sole profit arising from the efficiency of the naval and military services, the workmen employed are drawn from identical classes, and lastly it is the army and navy who are the consumers of the manufactured article. As regards the Government establishments, the wants of the navy and forces abroad parallel the requirements of the foreign customers of a private house; while the supply of the army at home may be compared to that of the population at large. We have seen that in either case the first essentials of success are the same—the presence of the raw material, the supply of skilled labour, and the facilities for distribution of the manufactured article. Nor is the parallel incomplete as regards strategical considerations; for as points of strategical importance are those spots in which many communications —such as roads, railways, rivers, and canals—meet together, so these junctions are always to be found in the centres of the greatest commercial activity.

Our Existing Establishments.

In 1716 the cannon foundry then existing at Moorfields, was removed to Woolwich. The chief reason assigned for the transfer was the presence of beds of loam in the neighbourhood, which afforded an admirable material for constructing the moulds required in casting; but it is probable that many other reasons concurred in the selection—such as the presence of the head-quarters of the artillery, and the facilities of water communication afforded by the river Thames. From an insignificant commencement, made little more than a century and a half ago, Woolwich has now attained its present enormous extension and importance. The following extract from a paper read before the Military Club at Versailles, and entitled "L'Armée Anglaise avant sa réorganisation," by M. le Baron de Mandat Grancey, the present French Military Attaché in London, may not be uninteresting, as being a foreign sketch of our great arsenal, and shewing the estimate of our military and naval manufacturing resources formed by one whose official position has given him ample opportunity of investigating them:—

"England only possesses one arsenal, and moreover, in principle, this arsenal suffices for the requirements of both the army and navy. The

arsenal of Woolwich—which furnishes employment to a number of workmen varying from 5,500 to 12,000 or 14,000, according to its requirements—sends out every year, on an average, 5,000 tons of iron shaped into cannon of all calibres, millions of cartridges, torpedoes, and the number of carriages, tents, and equipments required by the English army for its annual maintenance, as well as all the harness and saddlery for the cavalry and the artillery. The complementary establishments of Enfield, of Waltham Abbey, and of Pimlico, supply it with small-arms, with gunpowder, and with clothing and accoutrements; lastly, Sheffield furnishes its swords. But one would form but an imperfect idea of the resources in 'matériel' possessed by the United Kingdom, if one omitted to reckon the establishments organised, or ready to be so, by the efforts of private industry, and which secure to our neighbours the material means of almost unlimited action; for, in reality, England is the arsenal of the world."

Let us add a few more details to the summary furnished by M. de Grancey. The manufacturing establishments of the British army consist of—

1.	The Royal Carriage Department,	Woolwich.
2.	" Gun Factory,	Woolwich.
3.	" Laboratory,	Woolwich.
4.	" Gunpowder Factory,	Waltham Abbey.
5.	" Small-arms Factory,	Enfield.

In the estimates of 1873–4, provision was made for "the supply, manufacture, and repair of warlike stores" to the amount of one million and seventy thousand pounds. Of this sum, the Carriage Department absorbed £253,403, the Gun Factory £228,145, the Laboratory £381,589, the Small-arms Factory at Enfield £178,805, its auxiliary establishment at Birmingham £19,581, and the Gunpowder Factory £94,581; the total expenditure exceeding the estimate by many thousand pounds.

The cost of materials was estimated as follows:—

	£
Timber	32,202
Fuel	100,653
Metals	229,095
Saltpetre and sulphur	20,000
Total	381,950

The amount voted for the Clothing Establishments at Pimlico was £743,100; and of this sum, £502,121 was for manufactured clothing obtained by contract. Moreover, in addition to supplying the requirements of the army, this last-named gigantic establishment provides for the receipt, inspection, and issue of all clothing for the metropolitan police of London and Dublin, the employés of the General Post Office and the Custom House, and the Irish Constabulary.

From the foregoing figures some conception may be formed of the magnitude and importance of the interests we have at stake in our Government manufacturing establishments. Let us now proceed to

consider how far their centralisation, in so small an area, coincides with the principles laid down in the first portion of this essay. Firstly, with regard to strategical considerations. The policy of this country is, and has been for many years, an eminently defensive one; but in the pursuance of this defensive policy, partly owing to our insular position, and partly to our naval superiority, we have always hitherto been enabled to carry on an offensive warfare on the continent. For this purpose the situation of Woolwich is admirably adapted, provided we have not to contend with a naval power. The facilities for shipment afforded by the great port of London, and its vicinity to the shores of the continent, render the situation of Woolwich peculiarly favourable for supplying the wants of an army acting in France, Belgium, or the Low Countries. It has, however, been pointed out by the Commissioners on the Defences of the United Kingdom that we should find our arsenals very unfavourably situated in case of a war with a naval power like France. They observe:—"The difficulty that was experienced during the last war with France in passing vessels in safety down the Channel, will be much increased in future wars, owing to the introduction of steam as a motive power. Sailing vessels will be unable to pass the Straits of Dover without being in danger of capture by the steam cruizers of the enemy, which may be lying in wait in any of the Channel ports, and from whose rapid motion even the most efficient convoy will scarcely suffice to protect them; so that, unless the stores at Woolwich are transported across country to some western port, it will be extremely difficult to keep up communications with the out-stations in time of war." From the above it would appear that, even from an offensive point of view alone, Woolwich does not possess a very commanding situation. For the supply of India, however, and that of all our colonies, and garrisons to the eastward, Woolwich is no doubt most conveniently situated. Provided, also, that no enemy's cruizers should exist, or be able to keep the seas, in an European war, Woolwich—placed as she is on the main avenue of communication with the continent, viz. the Thames—forms a ready and convenient base for the supply of warlike stores to a British army acting on the continent. Let us now turn to the defensive point of view. Supposing that, by some sudden and unforeseen revolution in the wheel of fortune, we should be ourselves in turn attacked and invaded by a hostile army, it is difficult to state any point in which Woolwich is suited for an actually defensive warfare. It cannot be considered as in any way central as regards the other parts of the country. It is situated almost on the seaboard, instead of the interior of the country. An army beaten on the coast on the first landing of the enemy would naturally direct their retreat towards the capital and Woolwich, but neither the one nor the other possesses any fortifications to receive them. Such an army would, indeed, find ample means of armament and re-equipment, but no time would be given them for reorganisation. With an enemy following close at their heels, and pressing them *l'epée dans les reins,* they would have to turn and fight behind such hasty earthworks as might have been thrown up in the interim in the vicinity of the capital; and the issue of the battle would probably not only decide the fate of London and Woolwich, but that of

the whole of England. In fact, we might live to see the realisation of the clever conception of the author of the "Battle of Dorking." It has been said that the main arsenal and the capital of a state should not be immediately adjacent to one another; but London and Woolwich have this very fault. Provided the capital and the main arsenal lie widely apart, the enemy has at least to choose between two objectives. Either he may make for the capital, and having obtained possession of it, trust to the clamours of the civil population to obtain the submission of the forces still remaining in the field; or he may decide upon attempting to seize upon the main arsenal, and thence, with the chief source of military power securely in his hands, to proceed to the subjugation of the remainder of the country. When, however, the main arsenal and the capital are, so to speak, one and the same, there can be no room left for hesitation in the choice of an object. No amount of advantage gained elsewhere could equal that secured by the possession of the joint centres of military and political power; and these, being totally devoid of any means of prolonging the struggle by a passive resistance, might both fall at a single blow. Its immediate proximity to the capital apart, an arsenal which is chiefly calculated for offensive purposes more frequently than otherwise becomes an element of weakness when on the defensive, for it offers a point open to attack. We have but to consider the fate of Sebastopol, Metz, and Strasbourg to convince ourselves of this truth. As matters at present stand, there can be no doubt but that the question of protecting both London and Woolwich by a combined system of fortifications is one of paramount importance. With reference to this subject the Commissioners on the Defences of the United Kingdom report as follows:—"Whilst we are considering the protection of the vital points against which an enemy intent upon inflicting a heavy blow upon the country would direct his efforts, the question of the defence of London presents itself. There can be no doubt that the main object of an enemy invading this country would be to push for the capital, in the hope that if he succeeded in obtaining command of it, such a disaster would result in our buying him off upon any terms he might think it expedient to exact." We are aware that there are many persons who suppose that resistance would be prolonged in the provinces even after London and Woolwich had fallen into the hands of the enemy; but these expectations would appear to be rather founded on the somewhat gratuitous assumption that our population would prove itself more exceptionally brave and strenuous in its resistance to a foreign invader than that of other civilised countries, rather than on any well-founded calculation depending on a well-considered organisation of our resources and means of further resistance. Should we not rather find ourselves in the position described by Le Comte de Chapelle in his work entitled "Les forces militaires de la France en 1870"?—"It is only by making known the numerous resources which France possessed; by recalling the illusions which even the most competent men entertained as to the promptitude with which we could pass from a peace to a war footing, that people can be convinced that what was wanting above everything was neither men, nor horses, nor matériel, nor stores, but an organisation which would have admitted of the assembling of all

these elements at the proper moment on the spot where they were required to be employed."

It may be doubted whether even our own unrivalled manufacturing powers would enable us to reverse the scriptural saying, and, as it were, to turn our ploughshares into swords within the short interval in which modern campaigns are decided. When, at the commencement of the Italian war of 1859, the French War Administration found itself in critical circumstances as regarded the supply of clothing and boots for the army, an appeal was made to private industry throughout all the departments in order to supply the wants. This call only resulted, after two months, in the delivery of 10,000 pairs of shoes into the magazines; and similar difficulties were found to exist with regard to clothing. Again, at the commencement of the War of Secession, no less than thirty manufactories of small-arms were started in the United States; but they produced nothing the first year, and even at the end of two years could only succeed in turning out 2000 stand a day. On the other hand, *should time be given,* we might certainly to a great extent depend upon the private manufactories to compensate for the loss of the Government arsenal. Thus, in answer to an appeal of M. Gambetta, the private firms in France delivered to the Government of National Defence, within the space of five months, no less than 500 batteries, amounting to 3000 guns, with their carriages and ammunition complete. But the extent of England is small compared to that of France, and therefore the fate of the country would probably be decided in a much shorter time—the more so, as the investment of Paris occupied the major portion of the Prussian army, whereas, London occupied, an army invading England would be free to march at once in any direction it chose. With regard to the presence of the crude products required for the manufactures of war matériel, Woolwich, although originally selected for a foundry on account of the vicinity of loam suited for the construction of moulds, is unfavourably situated, as being far removed from the iron and coal-producing districts. The great facilities, however, which the place possesses in way of water-carriage, reduce this inconvenience to a minimum.

In the matter of facilities for manufacture, these latter have grown proportionally with the extent of the establishments themselves. At the present moment, probably there is no Government establishment in the world which can compete with Woolwich in the extent and variety of its plant and machinery, and its power of expansion in case of necessity. A large amount of skilled labour has been attracted to the neighbourhood, but it is chiefly already employed in the Government establishments, and the supply is not unlimited in case of an extraordinary demand arising.

The supply and the manufacture of war matériel come under different heads, but still they are both so intimately connected that it is scarcely possible to treat of one subject without alluding to the other. Looking upon the army and navy as the consumers of the war matériel manufactured at Woolwich, it must be conceded that it is well situated for the supply of war vessels able to take care of themselves; though not, as before stated, for the despatch of transports, when a state of war exists with

a naval power. It is also a good position from which to despatch warlike stores to India, the Cape, or the Mediterranean; but it does not possess the same advantages relatively to Ireland or Canada. As regards the supply of war matériel to the army serving in Great Britain, Woolwich is mistress of no very extraordinary facilities. Water communication certainly enables her to supply all the places on the coast or on navigable rivers with tolerable ease; but she is not situated on one of the great main lines of railway, and has no such facilities for supplying the troops in the interior of the kingdom.

Centralisation.

The manufacture of war matériel may have to be carried on under varying circumstances—such as peace, war, and civil strife; and the first of these being our normal condition, it should be our constant endeavour to prevent ourselves being caught unawares by the sudden advent of either of the two latter. It would probably be impossible to select a spot which would be equally advantageously situated for all three conditions; but by a judicious system of decentralisation we may succeed in establishing our manufactures of war matériel in different parts of the country, so that, whatever contingency may happen, at least one if not two of them may be available for all our requirements. There can be no doubt but that the present system of centralisation at Woolwich meets our requirements in time of peace, and it possesses, in fact, certain advantages of economy as regards supervision, and in the constant personal intercommunication of the heads of departments. It is in war time, however, that the sudden strain upon our resources takes place; and therefore during peace all our endeavours should be directed with a view to avoid any hitch during that critical period of the administration of an army which is comprised in the transition from a peace to a war footing. In like manner, as the army has to be increased in numbers at the moment of mobilisation, so also must the manufactures of war matériel be expanded to a degree enabling them to keep pace with the largely increased requirements of the army. We shall do well to arrange the machinery for effecting this critical transition from peace to war in time of the former, unless indeed we should prefer to find ourselves in the list of those whom General Trochu designates as "les gouvernements surpris en flagrant délit de préparation." According to General Hardegg ("Science de l'Etat-Major,") "the principal factors for calculating the time necessary for the completion of the war matériel in the event of mobilisation are:—

"(*a*) The degree of extension and excellence of the military manufactories and workshops, as well as of the workmen belonging to the state.

"(*b*) The well-founded prospect of a great or a small amount of competition for the supply of the stores required."

As regards the first-mentioned points, Woolwich certainly stands unrivalled; as to the last, in no other country could the efforts of private firms be calculated to produce greater results than in England. It

may, however, be doubted whether a sudden expansion of manufacturing power cannot be sooner effected in several establishments, each on a separate basis, than in one large one which would almost appear to have already attained a maximum of development. In the event of domestic dissensions, it is difficult to estimate how far Woolwich would be advantageously situated, or the contrary; for it is impossible to foresee in what quarter so fortunately improbable an event would arise. Happily for England, London contains at present no such dangerous population as the Communists of Paris; but did it do so, the proximity of our great arsenal to the capital would in this case also be a great element of danger to the state. Perhaps the most inflammable portion of the United Kingdom at the present moment is Ireland; and in the case of so unfortunate an event as a serious rebellion occurring in that country, an arsenal on the western coast would certainly be better adapted for supplying the necessary warlike stores than Woolwich.

Proposed System of Decentralisation.

During the late Franco-Prussian war, we have had presented before us the spectacle of two antagonistic systems pitted the one against the other. The system of excessive centralisation pursued by the French military authorities encountered that of decentralisation, on which the organisation of the Prussian army is so extensively based. The result was unmistakeably in favour of the latter, and it only remains for ourselves to profit by the experience which has proved so costly to others. Already we have introduced into our army administration the principle of decentralisation as regards men, and that of matériel must follow as a matter of course. The question of the inexpediency of massing our military manufactories and our supplies of warlike stores in one spot has already long occupied the attention of the Government of this country, but unfortunately no steps have as yet been taken to remedy the existing state of things. So far back as 1859, the Commissioners on the Defences of the United Kingdom recommended the establishment of a central depôt on Cannock Chase, and further expressed an opinion of the advisability of forming another great arsenal at Runcorn, on the Mersey. Both these sites would appear to be admirably adapted for all contingencies. We should then possess three great arsenals of construction in Great Britain; for, after all the outlay which has taken place there, and in view of the vast manufacturing power which has become gradually agglomerated there, we could never afford to disestablish Woolwich. Speaking generally, Runcorn and Woolwich would then manufacture all the war matériel required for the navy, while the central place of arms at Cannock Chase would minister to the wants of the army and reserve forces of Great Britain. In the words of General Trochu, we should thus effect that preparation for war "which consists in *échelonning* our resources and our existing means of resistance in a suitable direction." For purposes of distribution and supply, we should further require a certain number of second-class arsenals at the head-quarters of the more important military districts; while, for the less important ones, and for the sub-districts, third-class arsenals or minor depôts of supply would be established.

The following may be generally considered to be the distribution of war matériel:—

1. In hands of active army.
2. In store for army and reserve forces.
3. In course of construction.

Of the above, the last-mentioned, together with all the reserve stores intended for army and reserves, would be located in the three grand arsenals; while further reserves of matériel would be stored in the second-class arsenals, leaving it to the minor depôts of supply to take care of the equipment for immediate service required by the lesser tactical units on taking the field.

With such a system carefully and judiciously carried out, it would seem impossible for us to be surprised under almost any conditions. In peace we triple our means of production, we possess greater facilities for the judicious employment of contracts and private individuals for construction in case of need, and we retain the means of keeping up that skilled labor among the civil population which is essential for warlike manufactures; for the mind of man is progressive, invention leads to invention, and it is rarely that a sufficient accumulation of war matériel to render a suspension of manufacture desirable can be effected without the stores themselves becoming obsolete and requiring to be replaced by different patterns. War could scarcely make demands upon us which our increased powers of expansion would not enable us to meet, while the fact of each tactical unit starting from its own head-quarters completed with all the equipment necessary for taking the field, would render the organisation of the larger units almost complete at the moment of assembly. In civil strife we should probably find two, and certainly at least one of the three available for our requirements. In the extreme case of an armed rebellion in Ireland, Runcorn would be found to be situated in the most advantageous spot possible for supplying the army acting in that country.

Strategically speaking, in case of invasion and when on the defensive, we should possess three lines of defence instead of one—provided Woolwich and London were to some extent protected by fortifications, instead of being utterly defenceless, as at present. The fall of London and Woolwich together would not then necessarily involve the submission of the country; for the Court could withdraw to the north, while a fresh army assembled around the great place of arms at Cannock Chase would again try the chances of war. Even if unsuccessful in the field, the fortifications of the central arsenal itself would prove no small obstacle to an enemy's army. Protected as Cannock Chase might be by a species of quadrilateral, formed by fortifying the great strategic points of Birmingham, Rugby, Trent, and Crewe, we might form an almost impregnable place of arms. Supposing this also to fail us, our troops would still be able to make a final stand on the Mersey.

Turning to the offensive, we should find that the principle of decentralisation of war matériel would enable us to equip and organise armies with a celerity to which we have hitherto been strangers. In the event of war on the continent, India, or any of our colonies to the

eastward, Woolwich would supply war matériel to our forces; while in case of hostilities with a naval power occupying the channel ports, our convoys for the colonies could be despatched in safety from Runcorn. In like manner, Runcorn would form the chief point in our base of operations in case of hostilities occurring to the westward—such as an insurrection in Ireland, or a war in America. With regard to the position of the capital, we have already pointed out how its fall, even combined with that of Woolwich, need not paralyse the resistance of the country, which would still possess two strong *points d'appui* on which it could successively concentrate itself.

As far as concerns what we may call the material conditions of success in manufactures of all kinds, we have them present in abundance. Situated in the very heart of the coal and iron-producing districts, the place of arms at Cannock Chase would command unlimited supplies of the raw material at its very threshold. Nor would facilities of manufacture be wanting where skilled labor exists to any extent among a population almost wholly consisting of miners, colliers, mechanics, and artisans. The huge iron-works existing in the immediate vicinity afford the means of obtaining with ease any desirable quantity of plant and machinery for the use of the Government manufactories; while they are, moreover, capable of furnishing vast quantities of war matériel themselves. Again, if contracts be resorted to, we may allude to the vicinity of Birmingham—the great centre of the gun trade of the world—as affording a ready means of obtaining almost any amount of small-arms; of Stafford and Northampton—both famous for their shoe manufactories—for supplies of boots and accoutrements; and of Sheffield—the centre of the cutlery trade—for swords and all kinds of steel weapons and tools. Lastly, with reference to facilities of distribution. The depôts are supplied from the manufactories in three ways, viz.:—

1. By water.
2. By railway.
3. By road.

With regard to the first, the Thames and the Mersey give easy access to the sea both from Woolwich and Runcorn—thus affording a cheap and convenient means of communication, not only to all points on our own shores, but also to all parts of the world. Cannock Chase, again, is surrounded by a perfect network of railways, roads, and canals, communicating with all the principal lines and highways in the kingdom, and thus affording the ready means of supplying all the branch depôts in the interior of the country from the great parent arsenal.

It has already been observed that it is the army and navy who are the consumers of war matériel, and as our object is to facilitate its supply to them, we must necessarily refer to their distribution. The navy, of course, obtains its supplies of war matériel direct from the manufactories, or from the naval depôts, and need not here be further alluded to. The British army, however, is distributed as follows:—

In the United Kingdom.....	128,000
In India	63,000
In the colonies	16,000

With the question of the supply of our army and reserve forces we have already dealt, and second-class arsenals will suffice for the requirements of the comparatively few troops we still have left in our foreign garrisons and the colonies. The case of India, however, requires special consideration. It must be borne in mind that in that country we have not only to provide for the wants in war matériel of 63,000 British troops, but that we must also be able to satisfy the requirements of at least double that number of native troops. From what has been said before, we cannot attempt to supply the war matériel for so large a force entirely from England, without fatally contravening the laws of supply and demand. India produces the raw material required for the manufacture of war matériel in abundance. She is one of the greatest saltpetre producing countries in the world. She possesses wood for making charcoal, and is the home of the superior hard timber required for the manufacture of carriages. She has plenty of coal and iron, which it only requires time to develop. The raw material and the consumers being therefore on the spot, it is almost an economical necessity for us to retain manufactures of war matériel in India; but the conditions under which they have to be carried on are very different. We must never forget that in India we are only lodgers, and some day or other it may suit the landlady again to try and turn us out. The struggle of 1857–8 will then have to be repeated, perhaps under conditions more favorable to the enemy and not less disadvantageous to ourselves. Thus, that decentralisation in the manufacture of war matériel which we have assumed to be in England a tower of strength, would be in India a source of weakness; for it would simply be a multiplication of the points open to attack. At the present time, Bengal possesses 3 arsenals, 2 magazines, and 5 depôts; Madras 2 arsenals, 3 magazines, and 7 depôts; and Bombay 2 arsenals, 5 magazines, and 1 depôt; making a total for the whole country of 7 arsenals, 10 magazines, and 13 depôts. The existence of some of these is to be accounted for by the triad nature of the Government, exemplified by the three presidencies and their separate armies; but in any case it is evident that as the facilities of communication throughout the country are improved by the construction of roads and railways, we shall be able to dispense with a considerable proportion of them. In India the danger comes from within rather than from without; therefore, instead of placing our great arsenal and place of arms in the centre of the country, we must seek a position for it on the seaboard, wherever we possess the shortest and readiest means of communication with England, so as to be able to receive and equip our reinforcements on their arrival in the country. The mistake of collecting vast quantities of warlike stores in the interior of the country was exemplified by the magazine at Delhi; nor is it always to be expected that officers will be forthcoming so daring and devoted as, like Willoughby, to avert the consequences of such folly by the sacrifice of their lives. Signs are not wanting, however, that ere long we shall see effected a centralisation of the *personnel* of the three presidential armies under one Commander-in-Chief; and this cannot fail to be followed by a similar centralisation of matériel. The position of Bombay, situated as it is on the shortest line of communication with England, together with its magnificent harbor,

its great commercial activity, its large Parsee population, and its being the starting point of lines of railway leading to Madras, Bengal, and the Punjab, point it out as the most suitable locality for the centralisation of our manufacture of war matériel for India. With the exceptions of the Gun Carriage Manufactory at Futtehgurh, and the Harness and Saddlery Manufactory at Cawnpore, our present manufacturing establishments are either on the coast or within easy reach of it; and it may be argued that Calcutta and Madras will still require their separate manufactories in the view of war occurring in Burmah, or further to the eastward, in China or Japan.

Conclusion.

We have not, in the preceding pages, attempted to treat the question in any financial or economical aspect. The interests at stake are so great that we ought to hesitate at no pecuniary sacrifices which should make the event of invasion not only improbable but impossible. It is our business to profit by what we have seen with our own eyes in other countries, and we shall do well if we bear in mind these words:—"Personne ne sait, parce qu'il est réellement fort difficile de s'en rendre compte, jusqu' où va le gaspillage des hommes, des matières et de l'argent, dans une système où les efforts calculés et pondérés de la préparation de la guerre pendant la paix sont remplacés par les efforts pleins d'à-coups, et inévitablement rinneux de la préparation de la guerre pendant la guerre elle-même."

Staff College,
Farnborough Station,
31st March, 1875.

ANNUAL REPORT

AND

ABSTRACT OF PROCEEDINGS OF A GENERAL MEETING OF THE ROYAL ARTILLERY INSTITUTION, HELD ON MAY 20, 1875.

COLONEL W. C. F. GOSLING, R.H.A., IN THE CHAIR.

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1. THE Committee of the R.A. Institution beg to present their Annual Report to the general meeting of the members. It contains a statement of what has been accomplished during the past year, a summary of the present condition of the various branches, and some proposals which the Committee trust may meet with approval.

2. Committee meetings have taken place once a month, and oftener when required. At these meetings many questions have been discussed referring to the general management, the admission of honorary members, the exchange of "Proceedings" with foreign powers, &c. &c.

3. The Committee have complied, so far as possible, with a wish expressed at the last general meeting to the effect that the "Proceedings" should appear at regular intervals: the issues have been made quarterly, and have contained the original papers named in Appendix "A"; while the "Translations" in Appendix "B" have been brought out in a separate form but at the same dates. The Committee will endeavour to continue the periodical issue, but wish to reserve the power of making such alteration as may be rendered desirable by an inequality in the supply of matter.

4. The collection of coins in the possession of the R.A. Institution has been carefully arranged and placed in a suitable case by Lt.-Col. G. G. Pearse, R.A. The Committee consider that this officer is deserving of special thanks for the services so rendered, and they hope that members possessing any coins of interest will assist the collection.

5. A complete War Game, including maps of the country in the vicinity of Aldershot, Reading, Henley, and Knockholt, has been placed at the disposal of the members during the past year. The arrangements have been carried out by a Sub-Committee, and no expense has been incurred by the players.

6. On list "C" in Appendix will be found particulars of the Lectures which have been given in the R.A. Institution during the

winter. They have been few in number; and the Committee anticipate that in future it will be necessary to increase the amount set apart for this object, as it is found to be insufficient to enable them to secure the services of more than one or two lecturers of eminence.

7. The working of the Photographic Department cannot be said to be satisfactory, there appearing to be a loss of £50 upon the year, notwithstanding that the Committee reduced the number of attendances of the Photographer—and consequently the amount of his salary—by half. No lessons have been taken in Photography, and the only work done was the taking of portraits, for which the sum charged is not sufficient to cover the expense incurred.

Under these circumstances, the Committee propose to abolish the present arrangement and secure the periodical services of a first-class Photographer, to attend daily during the first fortnight of each quarter. Should members wish for instruction, a special arrangement will be made to meet their requirements.

8. The Committee have the pleasure of informing the meeting that H.I.H. the Prince Imperial, on completing his studies at the R.M. Academy, has graciously accepted an invitation to become an honorary member of the R.A. Institution.

The number of members is now 1485, as against 1441 last year; there have been 11 deaths, 11 withdrawals, and 66 members have joined. (*Vide* Appendix "D.")

9. There have been many additions to the Library, both by presentation and purchase. A list will be found marked "E."

10. Several officers have kindly sent specimens for the Natural History Museum, and a considerable sum has been expended in setting up type specimens. List of presentations marked "F."

11. The instruments in possession of the R.A. Institution are all in good order, and ready for the use of members at all times.

12. The financial state of the R.A. Institution is good, showing a general credit of £2532 9s. 1d. A detailed account of the expenditure and receipts during the year, and a Dr. and Cr. statement will be found facing this Report.

13. The subject for the Prize Essay this year was "Centralisation, as applied to the Manufacture of War Matériel."

Major-General F. M. Eardley-Wilmot, F.R.S., Brig.-General Sir J. M. Adye, K.C.B., and Colonel F. A. Campbell, C.B., were requested to be the referees, and kindly accepted the duty. Four essays have been received, read, and compared by the referees, who have communicated their decision in a letter which will be read to the general meeting.*

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* The letter being read, it was found that the referees had agreed to award the first place to the essay bearing the motto "Si vis pacem, para bellum." The envelope with that motto being opened, it was found that Captain C. C. Saxton, R.A., was the writer.

In connection with this, the Committee gladly take the opportunity of recording the satisfaction with which every artillery officer must have read the announcement that the medal given by the R.U.S. Institution, open to the army at large, and for which 79 essays were sent in, was won by an artillery officer—Captain H. W. L. Hime, R.A., &c., the first medallist of the R.A. Institution.

In proposing a most cordial vote of thanks to Major F. Duncan, R.A., the originator of the Prize Essay, the Committee submit that the scheme may be considered as thoroughly established, and should therefore now be placed entirely in the hands of the Institution. The question of providing a die for the gold medal is under consideration, and it is hoped that all the Prize Essayists may be supplied with medals before the next annual meeting.

14. The proposal for an addition to the Printing Establishment has again been thrown out of the annual Estimates. The Committee recommend that the work be executed under the supervision of the R.E. Department: estimated cost £300, to be defrayed by the R.A. Institution.

The rooms now used will be available, and are much required, partly as store rooms and partly to form a lathe room, well and comfortably fitted up.

15. The proposed alteration in Rule V. the Committee think would tend to a better state of affairs. As it at present stands, if the four members now longest on the Committee retire, there will be no member of more than one year's experience in the working of the Committee.

The following changes in the Committee have taken place during the year:—

Colonel G. Rotton,	replaced	Colonel T. W. Milward.
" R. P. Radcliffe,	"	" A. F. F. Connell.
Lt.-Col. H. Heberden,	"	" G. Rotton.
" W. G. Andrewes,	"	" M. B. Forde.
Major A. H. King,	"	Major S. H. E. Chamier.
" E. Staveley,	"	" F. Duncan.
" R. Sandham,	"	" E. Keate.
Captain C. C. Saxton,	"	Captain R. S. M. Mackenzie.
" S. C. Kyle,	"	Major E. Staveley.
Lieut. E. G. H. Bingham,	"	Lieut. G. H. O'Malley.
" W. E. Denison,	"	Captain C. C. Saxton.
" H. S. S. Watkin,	"	Lieut. E. G. H. Bingham.
Surg.-Major S. H. Fasson	"	Surg.-Major J. Gibbons.

The following officers retire, in accordance with Rule V.:—

Lt.-Col. F. Close.	Major E. Maitland.
" W. Stirling, R.H.A.	" J. F. Betty.

Major F. S. Stoney.

The following are elected:—

Colonel W. D. Aitken.	Major M. Le Fer Taylor,
Lt.-Col. A. H. Williams.	" J. Ritchie.
Major F. Lyon.	" W. G. Brancker.

If the alteration in Rule XVIII. be adopted, it is hoped that the classes will be better attended.

It appearing that the advantages of the R.A. Institution are imperperfectly known, a copy of the Rules will be forwarded with an early number of "Proceedings."

The following resolutions were proposed:—

1. *Moved by Major M. Le Fer Taylor, seconded by Major W. G. Brancker, and carried unanimously:—*

"That the Report be adopted."

2. *Due notice having been given, in accordance with Rule XX., the following alterations in the Rules (printed in italics) were submitted by the Committee:—*

"V. H.R.H. the Field Marshal Commanding-in-Chief to be Patron and President of the Institution. The Inspector-General of Artillery, the Commandant of the Garrison, the Director of Artillery and Stores, the Deputy-Adjutant-General, R.A., and such other officers as may be specially elected at a general meeting, to be Vice-Presidents. The affairs of the Institution to be under the direction of a Committee, consisting of the above officers, the Assistant-Adjutant-General, R.A., the Director of Artillery Studies, the Assistant-Adjutant-General, Woolwich, the Secretary, Department of Director of Artillery and Stores, and fifteen officers elected at the annual general meeting, of whom four shall be Colonels or Lieut.-Colonels, and one Medical Officer, the senior to take the chair. *No officer to be a member of the Committee for more than three years, or to be eligible for re-election until the expiration of one year after leaving office.*"

"XVIII. At the discretion of the Committee, assistance will be afforded from the general funds in support of all voluntary classes at the Institution; such assistance not to exceed *two-thirds* of the whole amount.

"*Members or honorary members wishing to join any class are to give notice in writing to the Secretary; and in the event of their requiring the use of the surveying or other instruments, they must make application to the Secretary.*"

"XIX. The Institution will bear a share of the expense of a class at any outstation at which as many as three of its members will combine for the purpose.

"The share of the expense borne by the Institution shall not exceed *two-thirds* of the whole expense of the class.

"The number of lessons to which the Institution will contribute shall not exceed one per week.

"The class to designate one of their number, who will engage to furnish a return of the members present at each attendance of the master and to manage the payments. An account to be sent quarterly to the Secretary of the Institution.

"*This rule not to apply to classes formed for the study of those Eastern languages for proficiency in which Government offers a reward.*"

3. *Amendment to Rule XIX., proposed by Major Le Fer Taylor, seconded by Major Brancker, and carried:—*

"That the paragraph restricting the number of lessons per week be omitted from the Rule."

The Rule, thus amended, was put to the meeting and carried.

4. *The Committee then proposed:—*

"That a sum not exceeding £100 should be placed at the disposal of a Sub-Committee for the purchase of a die. The Sub-Committee to have full power. Sub-Committee to consist of Major-General F. M. Eardley-Wilmot, R.A., F.R.S., the Deputy-Adjutant-General R.A., and the Secretary R.A.I."

The proposal was put to the meeting and carried unanimously.

A vote of thanks having been proposed to the Chairman, was carried unanimously, and the proceedings of the meeting terminated.

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GENERAL ABSTRACT

OF THE

INCOME AND EXPENDITURE OF THE ROYAL ARTILLERY INSTITUTION,

From 1st April, 1874, to 31st March, 1875.

EXPENDITURE.

		£ s. d.	£ s. d.
Printing	Wages	144 16 6	549 18 0
	Paper and Materials	336 9 6	
	Type and General Plant	2 11 0	
	Woodcuts	33 2 0	
	Lithography	32 19 0	
R.A. Institution Prize Essay			10 10 0
Chemistry			1 16 0
Photography	Salary	61 0 0	116 15 9
	Photographs	55 15 9	
Classes	Drawing	83 9 6	127 11 6
	Mathematics	44 2 0	
Lectures			37 5 0
Taxidermy			5 13 6
Library, and Books for Sale			331 17 0
Museum			73 6 0
Instruments			70 12 6
Carpenter	Wages	18 6 10	125 1 8
	Materials, &c.	106 14 10	
Furniture and Repairs			31 15 9
Subscriptions to Societies			4 4 0
Stationery			200 3 0
Postage and Parcels			76 17 10
Incidental			72 18 1
Wages to Clerks and Orderlies			140 1 5
War Office Photographs, Lithographs, &c.			16 11 11
Premiums for Fire Insurance	R.A. Institution in £5000	12 10 0	13 18 6
	R.A. Observatory in £1000	1 8 6	
Purchase of £313 14s. 5d. Consols			291 4 7
Power of Attorney for transfer of Consols Stock			1 12 6
Cash in hand, 31st March, 1875,	Secretary	86 19 0	271 13 2
	Messrs. Cox & Co.	184 14 2	
			£2571 7 8

INCOME.

		£ s. d.	£ s. d.
Cash in hand, 31st March, 1874			433 2 8
Printing			153 18 1
R.A. Institution Prize Essay			10 10 0
Chemistry			1 16 0
Photography			109 17 11
Classes	Drawing	44 1 10	73 8 4
	Mathematics	29 6 6	
Lectures			0 0 0
Taxidermy			5 13 6
Books sold			204 13 3
Museum			0 0 0
Instruments			0 0 0
Carpentry, Wood, and Picture Framing			55 14 2
Furniture and Repairs			0 0 0
Subscriptions	Entrance	64 0 0	1258 13 0
	1871-2	3 0 6	
	1872-3	16 10 6	
	1873-4	39 16 6	
	1874-5	1124 8 6	
	1875-6	10 7 0	
	1876-7	0 10 0	
Stationery			147 9 9
Postage and Parcels			44 1 1
War Office Photographs, Lithographs, &c.			17 13 3
Dividend on £1686 5s. 7d. Consols, for half-year ending 30th June, 1874.			25 1 8
" £2000 " " " 31st December, 1874.			29 15 0
			£2571 7 8

DEBTOR AND CREDITOR ACCOUNT FOR THE YEAR ENDING 31st MARCH, 1875.

DR.

	£ s. d.
Her Majesty's Stationery Office, for Books	19 16 8
Printing, Printing Paper, & Materials	16 12 8
Photography	9 2 2
Books, Periodicals, and Binding	13 12 2
Wood, &c., for Carpenter, and Picture Framing	8 7 2
Repairs	12 19 6
Stationery	14 8 1
Parcels	2 5 0
Incidental	2 0 1
War Department Lithographs	0 15 0
Postage of R.A. Lists, &c., charged to Members in advance for the ensuing 9 months	10 15 0
General Credit, 31st March, 1875	2532 9 1
	£2643 2 7

CR.

		£ s. d.	£ s. d.
Balance Cr.	Cash in hand	271 13 2	2121 13 2
	Consols Stock (at 92)	1850 0 0	
Value of Stock.	Books for Sale	15 0 0	119 18 5
	Stationery for Sale	12 10 0	
	Printing Paper	24 13 8	
	"Handbooks" (unbound)	30 18 9	
	"Kane's Lists" do.	16 16 0	
	Chemicals in Laboratory	20 0 0	
Owing by Members and others.	Printing	23 0 3	401 11 0
	Photography	14 12 2	
	Taxidermy	1 10 6	
	Books and Binding	57 3 3	
	Carpentry	25 6 11	
	Subscriptions	114 15 0	
	Stationery	116 3 11	
	Postage and Parcels	44 9 6	
	War Office Photographs and Lithographs	4 9 6	
			£2643 2 7

Examined and found correct,

R. RADCLIFFE, Col. R.A., President Sub-Committee.

WOOLWICH, April 26th, 1875.

W. H. KING HARMAN, Capt. R.A., Secretary and Treasurer.

APPENDIX.

A.

List of Papers published in the "Proceedings" during the past year.

Compound Guns, Many-Barrelled Rifled Batteries, Machine Guns, or Mitrailleurs. By Captain J. F. Owen, R.A., Captain Instructor, Royal Gun Factories.

Annual Report, and Abstract of Proceedings of a General Meeting of the Royal Artillery Institution, held on May 28, 1874. Colonel R. P. Radcliffe, R.A., in the Chair.

The Constitution and Duties of the Artillery of the Advanced Guard of an Army in the Field. By Lieut. S. C. Pratt, R.A. The R.A. Institution Prize Essay of 1874.

Index, &c., to Vol. VIII.

The Development of Field Artillery. Précis of the work "Development of the *Matériel*, Organisation, and Tactics of Field Artillery, from 1815 to 1870." By Captain Cooke, 22nd Regt., Topographical Department. (Communicated by the Director of Artillery).

Description of an Electric Chronograph, for the Measurement of minute portions of Time, &c. By Lieut. H. Watkin, R.A.

Explanation of Lock Action of "Gatling Gun." (In continuation of paper published in "Proceedings," No. 8, Vol. VIII.) By Captain J. F. Owen, R.A., Captain Instructor Royal Gun Factories.

Report of Trial of "Fire-proof Gunpowder Magazines." By Major V. D. Majendie, R.A., H.M.'s Inspector of Gunpowder Works. (Communicated by permission of the Home Secretary).

The Action of Discharge upon a Field Gun-carriage, as illustrated by the 16-pr. M.L.R. Gun of 12 cwt. By Captain W. Kemmis, R.A.

Curved Fire. By Count Bylandt-Rheidt, Major-General in the Austrian Service, President of the Technical and Administrative Military Committee. Translated from the German by Major J. R. Oliver, R.A.

Recent Improvements in the Manufacture of Pebble-Powder. By Major J. P. Morgan, R.A., Assistant Superintendent Royal Gunpowder Factory, Waltham Abbey.

Notes on Artillery in the Field. By Lieut.-Colonel W. J. Williams, C.B., R.A.

Experiments to Determine the Comparative Liability of Copper, Ordinary Bronze ("Gun-Metal"), and Phosphor-Bronze to emit Sparks when subjected to Sharp Friction or Percussion. By Major V. D. Majendie, R.A., H.M.'s Inspector of Gunpowder Works.

B.

List of "Translations" published during the year.

Use of Rifled Field Artillery. Translated, by permission, from "Les Conférences Militaires Belges," by Lieut. C. M. Smith, R.A.

Extract from the Report of the Swedo-Norwegian Artillery Commission, upon

various Systems of Mitrailleuses submitted to them. Translated from the French by Captain W. H. King Harman, R.A. Communicated by the Director of Artillery.

Notes from the "Austrian Military Journal," XV. Series, Vol. I., Parts 2 and 3 (February and March). Translated by Lieut. J. J. Congdon, R.A.

On the Artillery in the Khivan Expedition. From the Russian Artillery Journal for January, 1874 ("Artillerisky Jurnal"). Précis by Captain F. C. H. Clarke, R.A., Topographical Department, War Office.

Description of the Principal Foreign Artilleries. The Italian Artillery. Translated from the "Revue d'Artillerie," September, 1873, and April, 1874, by Captain J. F. Owen, R.A., Captain Instructor, Royal Gun Factories.

New Field Guns of the German Artillery. Translated from the "Revue Militaire de l'Etranger," by Captain E. H. Wickham, R.A.

Austrian Training of Cavalry in Jumping, Swimming, &c. Communicated by Lieut.-Colonel W. H. Goodenough, R.A.

Experiments to ascertain and compare the Effects between Infantry and Artillery Fire. Translated from the "Revue Militiare de l'Etranger," by Captain E. H. Wickham, R.A.

Historical Sketch of the Development of the Short 15 c.m. (5·94-in.) Gun, and its employment for curved fire. A précis of the Report of the Prussian Artillery Experimental Committee, by Lieut. H. Torkington, R.A.

List of "Short Notes" published during the year.

10-in. M.L.R. Carriage and Platform, Casemate, Mark II. By Captain W. Kemmis, R.A.

Description of the operation of Straightening the Brick Chimney-shaft of the Gas Works at the Royal Arsenal, Woolwich, in March, 1874, under the superintendence of Bt.-Lieut.-Colonel Scratchley, R.E., Inspector of Works, Manufacturing Departments, and Lieut. Watson, R.E.

The new Weapon for the Austrian Field Artillery. (Communicated by Lieut.-Colonel W. H. Goodenough, R.A.)

Table showing the Weights of the Carriages of Field Batteries in Marching Order with the Detachments Mounted. By Captain S. C. Kyle, R.A.

C.

List of Evening Lectures delivered at the R.A. Institution during 1874–5.

Professor W. F. Barrett, F.R.S.E. ...	"Sound, and its Analogy to Light, experimentally considered."
B. Waterhouse Hawkins, Esq., F.L.S., F.G.S.	"On the Unity of Plan, and Evidence of Design in the Vertebrate Animal Frame."
" "	"The Gorilla and Monkeys contrasted and compared with Man."
Major F. Duncan, R.A., &c., &c.	"The Royal Artillery and the Carlists: another chapter in the History of the Royal Artillery."
Professor W. F. Barrett, F.R.S.E. ...	"The Analogy of Sound and Light."

D.

Statement of Increase and Decrease of Members of the R.A. Institution during the year ending 31*st March,* 1875.

Rank.	31st March, 1874.	Additions.				Total additions.	Deductions.					Total deductions.	31st March, 1875.
		Promotion.	Retirement.	From retired list.	New members.		Promotion.	Retirement.	To effective list.	Withdrawal.	Death.		
EFFECTIVE LIST.													
General and Regimental Field Officers	436	32	—	—	2	34	—	2	—	3	—	5	465
Captains	281	50	—	1	5	56	32	—	—	1	2	35	302
Lieutenants	497	—	—	—	56	56	50	2	—	—	4	56	497
Paymasters	8	—	—	—	—	0	—	—	—	—	—	0	8
Quarter-Masters	5	—	—	—	1	1	—	—	—	1	—	1	5
Riding-Masters	5	—	—	—	—	0	—	—	—	—	—	0	5
Surgeons-Major	6	—	—	—	—	0	—	—	—	1	1	2	4
Veterinary Surgeons	3	—	—	—	—	0	—	—	—	—	—	0	3
RETIRED LIST.													
General and Regimental Field Officers	89	—	2	—	—	2	—	—	—	2	3	5	86
Captains	44	—	—	—	—	0	—	—	1	1	—	2	42
Lieutenants	11	—	2	—	—	2	—	—	—	—	1	1	12
Quarter-Master	1	—	—	—	—	0	—	—	—	—	—	0	1
Surgeons-Major	5	—	—	—	—	0	—	—	—	—	—	0	5
Surgeons	3	—	—	—	—	0	—	—	—	—	—	0	3
Veterinary Surgeons	1	—	—	—	—	0	—	—	—	1	—	1	0
Chaplain	1	—	—	—	—	0	—	—	—	—	—	0	1
HONORARY MEMBERS	45	—	—	—	2	2	—	—	—	1	—	1	46
Total	1441	82	4	1	66	153	82	4	1	11	11	109	1485

E.

Presentations to the Library, &c.

The Meteoric Theory of Saturn's Rings. By J. A. S. M. Davies, B.A., R.A.	The Author.
Contributions to the History of Explosive Agents. By F. A. Abel, Esq. 1st and 2nd Memoirs.	The Author.
Examination Papers R.M. Academy, February and July, 1874.	The Governor.
Hart's Army List for October 1873, April 1874, and July 1874.	The Committee R.A. Library.
Russian Artillery Journal. Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 1874.	Russian Government.
Requeil Militaire. Nos. 1, 2, 3, 1874.	Russian Government.

On a Cerannia of Jade converted into a Gnostic Talisman. By C. W. King, M.A.	Lt.-Col. G. G. Pearse, R.A.
Reports on the Necessity for the Amendment of the Law relating to Gunpowder and other Explosives, with suggestions for a new Act. By V. D. Majendie, Major R.A.	The Author.
Description of the International Bridge constructed over the Niagara River. By C. S. Gzowski	The Author.
Report of the Chief of Ordnance, 1873, to the Secretary of State, United States	The Secretary of State for War, U.S.
The Fenian Raid on Fort Erie, with an account of the Battle of Ridgway, June 1866	Riding-Master W. Donald, R.A.
Our Auxiliary Forces: a Lecture delivered before the Members of the United Service Institution of Plymouth. By Captain J. F. Owen, R.A.	The Author.
Catalogue of the Royal Gun Factory Museum, compiled by Major Maitland, R.A.	The Author.
Report on the State of the Militia of the Dominion of Canada for the year 1872–73 ...	Captain W. Kemmis, R.A.
Report on the Military Academy at West Point, United States. By Lieut.-Colonel Fletcher, S.F. Guards.....	
On the Geological Conditions affecting the construction of a Tunnel between France and England. By J. Prestwich, F.R.S.....	The Author.
A Manual of Instruction for Attendants on Sick and Wounded in War	Colonel S. E. Gordon, C.B., R.A.
Réglements et Articles pour la Discipline des Forces Militaires de sa Majesté Britannique du 24 Mars, 1781	
Researches on Explosives—Fired Gunpowder. By Captain A. Noble	The Author.
Reports on the State of the Militia in the Dominion of Canada, 1872–73	The Council R.U.S. Institution.
Der Indirecte Schuss mit Hohlgeschossen, Von Arthur Graf Bylandt-Rheidt	Karl Proschaska.
Die Mitwirkung der K.K. Genie-Truppe Beim Bane der Kaiser Franz Josef-Hochquellenleitung, Von Alphons Makowiczka	
Technical Training. By T. Twining	The Author.
Twelve Plates of Netherlands Artillery *Matériel*	Netherlands Government.
The Military and Naval Forces of the Austro-Hungarian Monarchy in 1873. By Dr. Jurnitschek (in German)	The Author.
Sketch of the Ground and of the Actions fought in the Pyrenees from the 25th to the 30th July, 1813	Captain C. C. Saxton, R.A.
Four Sketch Maps illustrating battle grounds in the Peninsula	
Ordnance Map of Salisbury Plain, 2 pp.....	
Sketch Map of Ashanti and Gold Coast.....	
Regulations of the Madras Military Fund. 2 copies	

Two Books of Plates of Prussian War *Matériel*	Lieut.-Col. R. O. Farmer, R.A.
Plates of Danish Artillery *Matériel*, LI. to LIX.	The Officers Rl. Danish Artillery.
Practical Geometry. By Rolla Rouse.	The D.-A.-General, R.A.
Second Report of the Director-General of Military Education, 1874	
Fac-simile of very curious old Map of Bermuda, now in the British Museum, published about the year 1626	Major-General J. H. Lefroy, C.B., R.A.
Treatise on Ammunition, 1874. 2 copies	Major W. R. Barlow, R.A.
Regulations for the Military Service in Prussia, (German), 6 parts	Major W. G. Brancker, R.A.
Breech-Loading and Muzzle-Loading for Guns..	The Author.
Recent Improvements in the Manufacture of Pebble-Powder. By Major J. P. Morgan, R.A.	
Artillery Retrospect of the last great War, 1870, with its lessons for Canadians. 2 copies ...	Major T. B. Strange, R.A.
Report on a Naval Mission to Europe, especially devoted to the *Matériel* and Construction of Artillery. By Captain E. W. Simpson, United States Navy. 2 vols., 2 copies of each	The Director, Bureau of Ordnance, U.S. Navy.
Duffla Expedition Map, North-Eastern Frontier of Assam	Secretary of State for India.
Russian Map of Central Asia, Persia, and India	Lieut.-Col. W. H. Goodenough, R.A.
Eight Plates of Austrian Artillery *Matériel*.....	
Le Siége de Belfort, 1870–71. Par M. Mény, Maire de Belfort	Colonel H. L. Chermside, C.B., R.A.
Report of the Final Examination at the Staff College, December 1874	The Director-General of Military Education.
Revue Militaire de l'Etranger for 1872-73. 2 vols.	The French Government.
Lectures delivered at the School of Military Engineering, Chatham :—	The Commandant, School of Military Engineering, Chatham.
Water Supply, Sewerage, and Sewage Utilisation	
The Art of Architecture, as applicable to Military Buildings	
Irrigation Works in India. By Lieut.-General Sir Arthur Cotton, K.C.S.I. ...	
Practical Engineering Construction. By G. H. Phipps, Esq., M.I.C.E.	
A System of Telegraphy. By W. H. Preece, C.E.	
Useful Tables. Compiled by W. H. Noble, R.A....	The Author.
Do. do. 6 copies	The Director of Artillery and Stores.
Greenwich Magnetical and Meteorological Observations, 1872.	The Astronomer Royal.
Militia Officers' Manual and Guide to Examination. By E. Lyons, Captain R.A.	The Author.
Proceedings of the Institution of Mechanical Engineers, October 1873, January, April, and August, 1874. Parts I. and II.	The Council of the Institution.
Proceedings of the United Service Institution of India. Nos. 14, 15, 16, 17, Vol. III.; No. 18, Vol. IV.	The Council of the Institution.

Journal of the Royal United Service Institution. Appendix to Vol. XVII., and Nos. 76, 77, 78, Vol. XVIII.	The Council of the Institution.
Proceedings of the Royal Geographical Society. Nos. 2, 3, Vol. XVIII.; Nos. 1, 2, 3, Vol. XIX. Journal of the Royal Geographical Society Vol. XLIII.	The Council of the Society.
Proceedings of the Scientific Meetings of the Zoological Society. Part III., 1873, and Parts I., II., III., 1874	The Council of the Society.
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Arundel Society Plates.

The Virgin and Child, with SS. Lorenzo, Guistiniani, and Zeno, from the picture by Girolamo Dai Libri in the Church of San Giorgio at Verona.
St. John the Baptist with St. Benedict, and St. Nazarus with St. Celsus, from the pictures by Bartolemmeo Montagna in the Church of SS. Nazzarole Celso, at Verona.

F.

Presentations to Museum.

2 Flamingoes	Captain J. R. D. Cooke, R.A.
3 Specimens of Bell Birds from British Guiana A Mantis, from Sikkim, N.W. India A Butterfly Moth, from Madagascar 10 Type Specimens of Birds	Mr. H. Whitely, Senior.
A Chinese Ornament of Coins (a Sword)	J. Long, Esq., Asst.-Controller.
An Iron Tobacco Pipe, and Steel and Flint, from Tibet	Major W. A. Kidd, R.A.
A Chinese Gun, taken by "B" Battery, 4th Bde. R.A., from the Summer Palace, near Pekin, in 1860	Colonel W. W. Barry, C.B., R.A.
6 Specimens of Birds from Jamaica	Major J. R. King, R.A.
A Bhotan Knife and Scabbard	Major C. W. Wilson, R.A.
A Native Shikarie's Rest for Fire-Lock A Scindee Snaffle-Bit	Lieut. F. B. Russell, R.A.

Birds from India, presented by Captain J. R. D. Cooke, R.A.

Phœnicopterus antiquorum (two specimens).

Birds from Jamaica, presented by Major J. R. King, R.A.

Todus viridis, (four specimens).
Certhiola flaveola. ♂
Merula leucogenys.
Merula jamaicensis.
Icterus leucopteryx.
Piaya pluvialis.
Piaya pluvialis.

Type Specimens, presented by H. Whitely.

Polyborus tharus.
Prosthomadera novæ-zelandiæ. ♂
Enicurus chinensis. ♂
Chibia hottentota. ♂
Sphecotheres australis. ♂
Casmarhynchus niveus. ♂ ♀ ♂, juv.
Trichoglossus cyanogrammus. ♂
Eclectus linnæi. ♂ ♀
Eunetta falcata. ♂ ♀

Specimens Set Up During the Year.

Milvago chimango.
Polyborus tharus.
Archibuteo ferrugineus.
" lagopus.
Circus cyaneus.
" æruginosus.
Otus brachyotus.
Dendrochelidon klecho.
Pelargopsis brumanica.
Arundinax olivaceus.
Orthotomus longicaudus.
Enicurus chinensis.
Anthus campestris.
Pomatorhinus erythrogenys.
Prosthemadera novæ-zelandiæ.
Sylvicola pensilis.
Parula americana.
Mniotilta varia.
Chibia hottentota.
Sphecotheres australis.
Oriolus galbulæ. ♂ ♀
Pitta bengalensis.
Myiobus tristis.
Arapunga niveus. ♂ ♀ ♂, juv.
Nucifraga caryocatactes.
Corvus corax.
Tanagrella ruficollis.
Spermophila olivacea.
Strobilephaga enucleater. ♂ ♀
Numia undulata.
Tockus ginginanus.
Pteroglossus aracari.
Aulacops castaneorhynchus.
Rhamphomelus nigrirostris.
Trichoglossus cyanogrammus.
Eclectus linnæi. ♂ ♀
Chrysocolaptes sultaneus.
Coccystes melanoleucus.
Oreopeleia violacea.
Goura coronata.
Chettusia indica.
Attagis gayi.
Coturnix communis.
Ardea comata.
" minuta.
Numenius phæopus.
Totanus glareola.
" glottis.
Recurvirostra avocetta.
Himantopus candidus.
Ibis falcinellus.
Rhynchæa capensis.
Phalaropus fulicarius.
Ortygometra crex.
Fulica atra.
Eunetta falcata. ♂ ♀
Chaulelasmus strepera.
Clangula histrionica.
Dendrocygna arcuta.
Melanetta deglandii. ♂ ♀
Mergus castor.
Puffinus major.
Sterna javanica.
Sula bassana.

A LIST OF SOME REMARKABLE AND IMPORTANT EXPLOSIONS OF GUNPOWDER WHICH ARE RECORDED AS HAVING OCCURRED PREVIOUS TO 1866.

COMPILED BY

MAJOR V. D. MAJENDIE, R.A.,

H.M.'S INSPECTOR OF GUNPOWDER WORKS.

The following list of explosions of gunpowder makes no pretence to completeness, or to absolute accuracy. Indeed, one of the objects with which it has been submitted to the Royal Artillery Institution is that those who are in a position and willing to do so, may, when they see it in the "Proceedings," supply its probably numerous deficiencies by sending me information with regard to explosions not here included of which they may be in possession; and I shall be very grateful to anyone who will furnish me with such particulars, or who will point out any inaccuracies as to dates or other details in this list, or who will supply me with confirmatory information relative to the different explosions here mentioned. I shall thus be enabled hereafter, I hope, to compile a more complete and reliable record of this class of accidents. In fact, I should like the present list to be regarded merely as a skeleton which, with the assistance of my brother officers and others, I hope to be able some day to fill up. But, incomplete as it is, this list of explosions does, I believe, offer sufficient points of interest to warrant its publication in its present form; and it is, so far as I am aware, the fullest record of the sort at present extant. A noticeable point is the large proportion of serious explosions caused by lightning. Particulars as to these have been mainly obtained from a little book called the "Thunder Cloud," by Professor Tomlinson. I am also indebted to some anonymous correspondents of "Notes and Queries" for a good deal of the information; and the details as to other explosions have

been culled from the "Annual Register," the "Dictionary of Dates," and various sources.

It is a remarkable circumstance that in three instances the number of persons killed is set down as 3000. There is a roundness about this figure which suggests grave doubts as to its accuracy; but the exact figure is of less consequence than the fact—of which there can, I imagine, be no doubt—that three explosions of a tremendously disastrous character did occur at the places named, in 1654, 1769, and 1794. Other explosions of a very formidable description are recorded, by which 1000, 400, 300, 200, 180, and (on two occasions) 100 persons respectively are said to have been killed, and immense damage was done to property. Here, also, I do not think too much importance should be attached to the precise figures—which appear open, in nearly all cases, to very considerable doubt; but the fact that records exist of so large a number of very fatal explosions, shews that the apprehensions of danger from explosions which is periodically excited by such accidents as the one which ocurred at Erith in 1864, and the more recent explosion in the Regent's Park in October, 1874, are by no means fanciful or exaggerated, but may be justified by an appeal to actual occurrences. Of such occurrences, the well-authenticated explosion at Leyden, 1807—by which 200 persons are said to have been killed, and a large portion of the town to have been destroyed—and the explosion at Eisenach, in 1810—by which it is recorded 54 persons were killed, and great damage was done to property—afford suggestive examples, and illustrate very effectively the dangers which may arise during the transport of gunpowder through populous places.

Several minor accidents are included in this list as having occurred at gunpowder factories, and I have hesitated as to whether they ought to be mentioned; but I have determined on doing so, on the ground that they are contributions towards the more complete record of explosions which I am not without hope of being able to compile hereafter, and also because the importance of an explosion is not always to be measured by the resulting loss of life—a point which is well illustrated by the Regent's Park explosion, where only three persons were killed, but where the damage to property was very extensive, and by the explosion of the "Lottie Sleigh" at Liverpool, when no lives were lost.

HOME OFFICE, WHITEHALL,
1st July, 1875.

Date.		Place.	Number of persons killed.	Number of persons injured.	Nature and extent of damage to property.	Cause of explosion.	Remarks.
A.D. 1649	1 Jan.	London, Tower Street ...	?	?	60 houses blown up.	?	37 barrels of gunpowder exploded in a shop.
1654	—	Gravelines	3000	?	Explosion of magazine.	?	
1658	11 Mar.	Hounslow Mills.....	Nil.	—	—	?	3 explosions (unattended with loss of life).
1658	6 Aug.	Hounslow Mills.....					
1658	29 Dec.	Hounslow Mills.....					
1693	—	Dublin	100	—	—	?	218 barrels of gunpowder exploded.
1739	10 Sept.	Bremen	40	—	1000 houses destroyed	Lightning.	
1762	11 Aug.	Worcester	?	?	Town greatly damaged.	"	
1762	15 Oct.	Goree	—	—	Goree nearly destroyed.	"	
1765	3 Dec.	Waltham	—	—	Two mills blown up.	?	
1767	1 Jan.	Faversham, Royal Mills.	—	—	Mills blown up.	?	
1768	10 May	Ewell.....	—	—	Destruction to the amount of £8000.	?	
1769	18 Aug.	Brescia.....	3000	—	—	Lightning.	
1769	—	Venice	400	—	—	"	
1770	1 Sept.	Faversham	1	—	1 horse killed.	?	
1770	27 "	Hounslow	1	—	—	?	
1771	18 "	Moulsey	3	—	—	?	
1772	6 Jan.	Hounslow	—	—	Three powder mills blown up.	?	
1772	—	Trichinopili.....	300	—	Trichinopili blown up; 340,000 ball cartridges destroyed, and the whole foundations shaken	?	
1772	5 Nov.	Chester.....	See remarks.	—	Several houses greatly damaged.	Lightning.	Destroyed many spectators at a puppet show.
1773	—	Cambray	18	—	Several houses destroyed.	"	
1773	—	Abbeville	150	—	100 houses destroyed.	"	
1774	24 Apr.	Hounslow	2	—	—	?	
1776	20 Aug.	Picardy	Several.	—	—	?	
1777	16 "	The Epsom Mills	—	—	Mills blown up.	?	
1779	26 June	Vienna	Several.	—	Town received great damage.	?	
1779	Sept.	Civita Vecchia	—	—	Civita Vecchia nearly destroyed.	?	
1780	18 Aug.	Malaga.....	—	—	—	Lightning.	
1782	Mar.	Sumatra	—	—	—	"	
1785	4 May	Tangiers	—	—	—	"	
1789	11 Mar.	Corfu	180	—	Magazine destroyed.	Fire.	72,000 lbs. of gunpowder and 600 bomb-shells blew up.
1789	3 Oct.	Faversham	1	—	—	?	
1790	12 "	Dartford	6	?	Great destruction occasioned.	?	
1792	28 June	Poland, Luban	90		Two synagogues and a great number of houses totally destroyed. All the windows in the town broken.	Fire.	The axletrees of ten carriages took fire that were conveying gunpowder to the army, occasioning a dreadful explosion.
1793	10 July	Bayonne	100	—	The chapel at the new castle was blown up.	?	
1793	Sept.	Youghal	?	?	Barracks blown up.	?	
1794	3 "	Grenelle, near Paris.....	3000	?	All the adjacent buildings destroyed by the blowing up of powder mills.	?	
1794	20 Dec.	Landau.....	?	?	Arsenal blown up.	?	
1794	31 "	Dartford	11	—	—	?	
1796	14 Jan.	Hounslow	3	—	Much property destroyed.	?	
1796	10 Aug.	Dartford	4	—	—	?	
1798	20 May	Battle	3	—	Much property destroyed.	?	
1799	14 Jan.	Dartford	3	—	—	?	
1799	13 July	Twickenham Common...	4	—	Mill exploded.	?	

(*Continued.*)

Date.		Place.	Number of persons killed.	Number of persons injured.	Nature and extent of damage to property.	Cause of explosion.	Remarks.
A.D. 1800	28 May	Nantes	Many.	—	Magazine blew up; many houses destroyed.	?	
1801	20 Mar.	Battle	1	—	—	?	
1801	25 Apr.	Waltham Mills	9	—	Mill exploded.	?	
1802	8 Sept.	Faversham	6	—	3 horses killed.	?	
1805	15 June	Dartford	2	—	—	?	
1805	1 Oct.	Edinburgh, Roslin	2	—	Mill exploded.	?	
1807	Jan.	Leyden	200	—	The most magnificent part of Leyden (about 300 houses) blown up, by the accidental explosion of a vessel lying in the Rapenburg canal, laden with gunpowder.	?	
1807	26 June	Luxembourg	?	—	—	Lightning.	
1807	18 Sept.	Faversham	6	—	3 horses killed.	?	
1808	9 "	Venice	—	—	—	Lightning.	
1810	16 Jan.	Faversham	6	—	2 horses killed.	?	
1810	2 Sept.	Eisenach	54 citizens, besides escort.		Three French powder wagons blown up; 28 houses destroyed, and large portion of town set on fire.	Spark from horse's hoof set fire to spilt powder.	
1810	24 Sept.	Dartford	2	—	—	?	
1811	27 Nov.	Waltham Mills	1	—	—	?	
1812	4 July	Hounslow	—	2	—	?	
1812	14 "	Roslin	2	1	Mills blown up.	?	
1813	21 Aug.	Hounslow	3	—	Two explosions.	?	
1814	Sept.	Battle	3	—	—	?	
1816	16 Apr.	Toulouse	16 (about.)	several.	Mills exploded.	?	
1817	3 Oct.	Faversham	3	—	—	?	
1818	19 Mar.	United States, Brandy Wine	30	10	Powder mills blew up.	?	
1829	28 Nov.	Navarino	?	—	—	Lightning.	
1840	6 June	Bombay (magazine)	?	—	—	"	
About same time.		Dum Dum	?	—	—	"	
1843	13 Apr.	Waltham	7	—	Four buildings overthrown.	?	
1843	22 "	Sicily, Puzzaloni	?	—	—	Lightning.	
1843	23 "	Spain, Gaucin	?	—	—	"	
1850	11 Mar.	Hounslow	8	—	Three explosions.	?	
1853	—	Hounslow	?	—	—	Lightning.	
1855	7 Oct.	Liverpool, firework factory, Green Street	5	—	—	"	
1856	6 Nov.	Rhodes	?	—	—	"	
1857	10 Aug.	Bombay, Joudpore	1000 (about.)	—	—	"	
1859	30 Mar.	Hounslow	7	—	Mills again blown up.	?	
1859	6 Aug.	Ballincollig (near Cork).	5	—	—	?	
1860	10 Sept.	Argyleshire, Melford Powder Mills	6	—	—	?	
1860	1 Dec.	Norwich	2	—	Explosion in a shop; destroyed much property.	?	
1861	21 Jan.	Chatham, Government manufactory for hand grenades	1	several.	—	?	
1861	27 May	Waltham Mills	1	others.	Mills blew up.	?	
1862	9 Sept.	Cornwall, Nance Kuke Powder Mills	6	—	—	?	
1864	9 Jan.	Liverpool, "Lottie Sleigh"	Nil.	—	Vessel with 11½ tons of gunpowder on board.	By ship catching fire through unexplained ignition of a quantity of "Parafin oil."	The steward was in the act of filling from a can into a lamp; can was dropped by steward, and flaming contents flowed along cabin floor and ignited curtains and bed clothes, and then flowed through grating of lazarette and ignited cargo in after-hold.

(*Continued.*)

Date.		Place.	Number of persons killed.	Number of persons injured.	Nature and extent of damage to property.	Cause of explosion.	Remarks.
A.D. 1864	1 Oct.	Erith	?	?	Messrs. Hall's magazine, and magazine belonging to Lowood Gunpowder Company; both blown up, with about 57 tons of powder.	?	Immense damage to property, and considerable loss of life.
1864	9 Dec.	Buenos Ayres	160	—	—	?	
1864	24 "	United States, Wilmington	—	—	Powder vessel exploded, without damage.	?	
1865	29 Mar.	Faversham	—	2	—	?	
1865	11 Apr.	Southwark	—	—	Four or five barrels of powder exploded in a shop.	?	
1865	24 May	United States, Mobile	200 (about.)	—	?	?	
1865	21 Sept.	Manchester, firework factory	—	—	?	?	
1865	25 "	Ewell, powder mills	2	—	?	?	
1865	26 "	Bristol, firework factory.	—	—	Manufactory blew up.	?	

NOTES

ON

GUNNERY INSTRUCTION.

BY

LIEUT. G. MACKINLAY, R.A.

The N.C. officers and men composing a squad sent to Shoeburyness for a long or short course of instruction, seldom fail to work hard and gain a good practical knowledge of their profession. These are, however, selected men, sent to the very focus of artillery life, where the most perfect *matériel* of the newest patterns are at hand to stimulate the desire for information; they will not in all probability go through a similar course again; they are free from all other duties, and so able to learn without interruption; last, but not least, they have the incentive to study supplied by the prospect of future advancement consequent on good progress.

But the squads which come under a brigade gunnery instructor are differently constituted and circumstanced. Instead of selected men, he has to deal with all, including the ordinary rank and file—many of whom are naturally wanting in education and intelligence; the *matériel* at his disposal is often limited in quantity and obsolete in quality (especially in India); so that it is difficult to excite much zeal in the men of his squads, more particularly as the courses recurring year after year are apt to become monotonous, and are of necessity frequently interrupted by the performance of other duties. It is therefore evident that there are some difficulties in the latter case which scarcely appear in the former; and from this it would follow that the method persued in the one case may not always be applicable in the other. It is proposed in the present paper to discuss the means for facilitating the instruction of the men with their batteries.

Three objects should be aimed at in instructing the men:—

1. Their full attention should be gained and kept.
2. Only language which they clearly understand should be employed.
3. Efforts should be made to prevent their forgetting what they learn.

To attain the First Object.

Favourable reports and probable promotion* may be promised to those who make best progress in the course, while others may be induced to come up to a certain standard by the prospect of exemption from elementary drills and lectures on a future occasion. In the infantry, men try hard to qualify as 1st-class shots in order to escape position drills, &c.; and in the army at large, private soldiers will work for and pass 3rd-class army examinations, so as to be free from more schooling.

If the instructor relates frequent incidents and anecdotes bearing on his subject in teaching, the men's attention will not only be gained, but they will be furnished with a *memoria technica* for remembering facts. Whenever an easy reason can be given it will always be found to excite attention and aid the memory. Simple experiments, diagrams, and models are all useful, as they enable men to learn by means of their eyes as well as their ears.

Each subject of a lecture should have some connection with the preceding one, as it will then be more easily followed and remembered by the men than one consisting of disjointed sentences. For instance, after speaking of shot, the subject of shell comes better than gun-pits, as the sequence of ideas is more apparent. As he should have as little recourse to notes as possible in lecturing, the instructor himself finds the advantage of delivering a lecture which he can easily carry in his head.

Lectures should be short and frequent, rather than long and few; they should also be as little formal as possible. A few explanatory words in the midst of drill may often teach more than an elaborate description in the model-room.

Preliminary questions should be put to the men, and some who have had special acquaintance with the subject to be discussed should be drawn out to give information; as this will cause all to take an active instead of a merely passive interest in the matter.

Questions should be encouraged from the men, so that explanations may be given on points not understood. A plan is adopted in a Berlin working men's club, after a lecture on a scientific subject, of putting written questions on it into a box, which is then taken to the lecturer, who reads the questions and answers them before his audience.

The necessity of gaining the interest and attention of men under instruction is only briefly alluded to in our drill-books, but the Prussians seem to consider it a point of the greatest importance, as will be seen from the following extract from their "Cavalry Field Duty":—†

"Theoretical should precede practical instruction, and no pains should be spared by the instructors to make their men like and take an interest in what they are taught.

"Those, however, who wish to learn are especially recommended to think out in their minds all they have heard. They should ponder over it,

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* Before rising each step in rank, a N.C. officer should be required to pass an examination in drill and gunnery.

† Translation by Captain Russell, 14th Hussars.

they should question and talk to each other regarding it when they are together—for instance, when they are on guard, in their barrack-rooms, when they go out for a walk; in fact, they should never rest until they have a clear and distinct conception of what has been told them and of what they have read.

"A good way of impressing on the memory the principles of field duty, is to endeavour to picture to one's mind those situations or circumstances of war of which one has heard or read, or to which the attention has been directed. The instructors and the older and experienced soldiers will gladly assist their younger comrades, who thus gradually will clearly and distinctly understand how to act under the various circumstances which may occur. This theoretical study will be of great use to the men, both when they receive practical instruction and when they go on service."

The tedium of the most wearisome drill may be greatly removed by making the men understand the reason of everything—as, for instance, why each man does his particular work at gun drill.

If two squads are constantly drilled together at the same thing, a little rivalry is excited between them, and more interest is aroused than if they work separately.

Drills should be as practical as possible. For instance, a detachment will work with greater zeal if ordered to lay as many times as possible on a ship passing an embrasure, than if the guns are always pointed on a fixed bull's-eye.

As a variety, and to give an intelligent knowledge, supernumeraries at drill may occasionally be ordered to place small numbered blocks of wood in the positions of the men at drill.

To attain the Second Object.

Ordinary military books must be translated into the simplest language. This is more difficult than appears at first sight, as it takes some time to find out that the commonest expressions convey no ideas whatever to some of the less educated of the men; and so definitions and terms must be explained in almost childlike language—which is by no means always easy to do.

Care should be taken that all drawings, models, &c., are as simple as possible. A few lines drawn on a black board will generally afford a better illustration than an elaborate section or plan, as most of the men cannot understand them. The W.O. lithographs are beautifully executed, and are most useful for shewing to the more intelligent and educated; but a very large proportion of the men see no more resemblance between a fuze (for instance) and its lithographed section than a savage does between a man and his photograph—simply because they are unaccustomed to making the comparison.

There is a common saying which contains a considerable amount of truth, that one who has just learnt a subject is the best person to teach it to others; as, of course, he is fully alive to all the difficulties which beset a learner's mind, from having just passed through them himself.

Therefore, soldiers who have mastered a subject spoken of in a lecture should be encouraged to explain to those who do not understand it.*

To attain the Third Object.

Information should be presented, as already remarked, in a manner easy to remember.

Questioning will recall facts to the minds of the men, and so prevent their forgetting what they have learnt. In his annotations on Bacon's essay of "Study," Archbishop Whately remarks on the words "conference (maketh) a ready man," that "what is properly to be called instructive questioning," (distinct from questions of examination) "is employed by all who deserve to be reckoned good teachers."

If the men practically carry out† as far as possible what they have been taught, there is less chance of their forgetting it than if they are only spoken to on the subject. For instance, a man may be told how to make a spar bridge, but unless he actually constructs one he is not likely to remember much about it. In fact, in learning, the men must employ their tongues and hands as well as their ears and eyes.

In India, all artillerymen are ordered to be instructed for 42 hours annually, previous to the practice, by their subaltern officers. If what has been said in the preceding paragraphs be true, it is evident that although an officer may be thoroughly instructed himself, he must undergo considerable trouble and labour in order to teach his men in the best way. Gunnery instructors have their attention confined to this subject, and they have time to work out plans according to the best of their abilities; but it must of necessity take anyone a long while to find out the most successful method of teaching.

The directions contained in the standing orders of the regiment and the drill-book on this subject are rather few and general. Would not a great advantage be secured by obtaining and publishing a more definite system of instruction, containing something like the following:—

(1) A few practical hints on the art of teaching.

(2) Outlines of lectures, illustrated with very numerous incidents and anecdotes from actual experience.

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* It does not follow from this that the instructor himself should know but little more than his men. The very reverse should be the case. The best lecturers on scientific subjects to unlearned audiences—Tyndal, Huxley, Bloxam, and others—are men of deep knowledge. When Faraday gave evidence before the Public Schools Commission, he said one day, "The difficulty of teaching chemistry in schools will be to find men competent to teach it." "What! in its first rudiments?" asked the Commissioners; to whom he replied, "The teachers of first rudiments should be deeply versed themselves." The same rule must hold good in teaching artillery and gunnery.

† As the delivery of effective fire is the great object of artillery, it would appear that a certain number of rounds (of shell especially) might be usefully expended for instructional purposes, when the principles stated in theory could be practically illustrated.

In India, in *garrison* batteries, all the annual allowance of ammunition is expended in competition. For instructional purposes this is not so useful as it might be; because the officers in charge are unable to correct or even point out the mistakes which the men make in firing, as thereby an unfair advantage would be given to the men who fire after each error is noted. Of course mistakes can be explained when all the practice is over; but by that time probably nearly all the circumstances connected with them are forgotten, and little impression is made on the men's minds.

For horse and field artillery there should be thorough instruction in the guns, ammunition, and stores used by the battery, and only a general knowledge of those belonging to others. Some idea should be given of the use of artillery fire in the field, the rate of firing under different circumstances, and the object to fire at—which cannot usually be well understood unless the general object of a battle is known—the best positions for artillery in action and on the march, and the relation of this branch to the cavalry and infantry; as an intelligent knowledge on these points is most necessary to the mounted portion of the regiment, in which rapidity of understanding and carrying out orders is of the highest importance—the object of instruction being more to teach the men how the guns, ammunition, and stores of their batteries should be employed on service than how they are made in arsenals, for the same reason that a sailor is taught more about navigation than naval architecture.

With garrison artillery the chief attention must, of course, be given to becoming acquainted with the very many natures of ordnance, ammunition, and stores which the garrison gunner may be called upon to use. The unavoidable slowness in the working of heavy guns affords time to the officers to prevent mistakes; but even garrison artillerymen should be taught something of the relation of the different branches of the service to each other, and of the general plan of sieges, &c., as was proved at the second siege of Badajos, when "the ricochet fire of the batteries was less effectual than might have been expected, but none of the distances were more than 600 yds. The lines to be enfiladed were short, and it required the greatest attention to keep the artillerymen—particularly the Portuguese—to the proper system of direction for this species of fire. They would not believe that they were doing good in firing over the parapet, and they preferred striking the wall whenever they could do so unobserved; and this was done to such a degree, that the left face of the bastion La Trinidad was very much injured at the salient angle."*

(3) Some questions and answers, in simple language.

(4) A few directions about teaching drill, and practicly carrying out the subjects taught.

The publication of some such system would facilitate the work of every officer engaged in teaching, and the men would be instructed in a more rapid, uniform, and thorough manner than at present—an advantage which is hardly perceived in time of peace, but which becomes one of the first importance on the breaking out of a large war, and the consequent enlistment of numbers of recruits, whose time for training is often limited.

A well prepared system promotes both discipline and *esprit de corps;* as the more a man interests himself in his profession, the better will he do his work.

The various conditions of the different batteries of the regiment would prevent any rigid adherence to such a system, which should be but a sketch to be filled up according to circumstances and the discretion of

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* Jones' "Sieges."

the instructor, who will always teach best when allowed to proceed in his own way.

Some such system, for instance, as that carried on during the past two years in the Lahore Division (of which a short description is here given) might be adopted:—

On each subject a short lecture of from half to three-quarters of an hour is given, illustrated as fully as possible by short incidents, diagrams, and experiments on a simple scale.

The class is then broken up into squads of convenient size, each under a N.C. officer. (In field or horse artillery batteries, subdivisions under their own Nos. 1 are employed). A card containing questions and answers on the lecture just delivered is then given to each N.C. officer in charge of a squad. Each card contains different questions, and is accompanied by any diagrams, sections, stores, models, &c., procurable referring to it.

The N.C. officers are then directed to read the questions and answers on their respective cards to their squads, and to shew the diagrams, &c. After this, they teach their men the answers.

Meanwhile, the officer in charge moves from squad to squad, to ascertain that the men really understand the answers, and are not learning them by rote. He finds out what difficulties exist, and removes them if the N.C. officers are unable to do so. When he is satisfied that each man knows all the answers on his N.C. officer's card, he orders an exchange of all the cards, with, of course, their accompanying diagrams, &c. (In a field battery, N.C. officer of No. 1 subdivision gives his card to No. 2, 2 to 3, 3 to 4, 4 to 5, 5 to 6, and 6 to 1).

The N.C. officers then read over their new questions and answers, and teach their men as before. In this way, after six changes of the cards in a field battery, every man will have learnt all the answers on all the cards.*

The subject lectured on is then gone into practically, and the men carry it out at drill or repository exercise as fully as possible, being occasionally questioned, to see if they understand what they are about. Frequently, while at drill, the questions and answers or short explanations are introduced, in order to give variety.

Notice is given at the end of each attendance of the drills or exercises to be performed at the next, and the N.C. officers are directed to read up the drill-book on the subject. At the next attendance, after the instructor or his serjeant has performed an exercise, one of the N.C. officers is ordered to repeat it.†

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* By adopting this system of questions and answers, each man can have more attention bestowed on him than if a large number are questioned by an officer. The men also answer and state their difficulties more readily to the N.C. officer of a small squad than to an officer in presence of all their comrades. The difficulties which present themselves to the men's minds can be removed by explanations, since opportunities are offered for finding them; while in ordinary lectures an officer may unknowingly continue to use language which his men do not understand. The N.C. officers are also obliged to keep up their knowledge in order to explain to their men.

† No amount of reading, instruction, or even actual experience as a working number at repository exercises gives the confidence in directing others, and the facility and skill required in overcoming the small difficulties which arise, without actual experience in the responsibility of the charge of a squad at drill. All but the most necessary interference with the N.C. officer should be avoided, as it distracts his attention and hinders him in gaining self-confidence.

No novel principles are involved in this method. Questions and answers have always been employed in teaching, and a book full of them is one much read at the present time by infantry officers when preparing for examinations for promotion. Several little works have appeared during the last few years explaining military subjects in simple language —as, for instance, Captain Orde Browne's "Short Notes on Field Batteries," and a pamphlet on Armstrong guns by an "Artilleryman," whose explanation of the way segments are placed in a segment shell, like bricks in a tower, is one always understood and remembered by the men; but (as far as the writer in a remote Indian station is aware) no systematic attempt has been made to present all the information required by artillerymen in a shape suited to them.

The most important part of practical gunnery is, no doubt, the obtaining of accurate and rapid fire. All authorities seem agreed that accuracy is the first desideratum, and that a careless even though rapid fire is not to be encouraged; as was well stated by Sir Garnet Wolseley in his orders to the troops previous to the Ashantee war:—"Every shot that is not deliberately aimed not only encourages the enemy—who would soon learn to despise a fire that did them no injury—but seriously affects the efficiency of the force: if ammunition were to run short, a stop would be put to our further advance." But as it has been found with the infantry that breech-loaders greatly increase their efficiency, by giving them the power of very rapid fire when required, so with artillery (especially horse) the power of increased rapidity of fire (supposing accuracy is still maintained) must give increased efficiency.

As a rule, gunners are too slow in laying. Every man can lay a gun with accuracy, if he is only well taught and has plenty of time; but only a few can combine rapidity with accuracy. Those few should be selected, and the utmost advantage taken of their abilities by special training in laying the guns. This has been carried out to a certain extent in India by allowing only thirty men specially qualified in each battery to lay the guns at the annual practice; a competition takes place among them, and the ten best receive the honourable title of "marksmen," but no pecuniary reward, as in the infantry.

Experiments were made last cold weather and are being repeated this season in India for testing the accuracy of artillery fire at dummy infantry behind cover during a certain number of minutes. This country offers advantages for these experiments not easily obtainable in England, as unknown ground on which the ranges are not familiar can generally be fired over.

Of course nothing but constant practice can make men good and rapid shots, and therefore laying should be constantly practised at drill; but it should be made as interesting as possible, by varying the objects aimed at, and exciting emulation by sometimes timing the rounds and finding out who can lay quickest, the instructor always noting if the guns are laid accurately. Laying on moving objects* may also be useful. A man is ordered to move across the gun at some distance in

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* *Vide* "Translations issued with Proceedings, R.A. Institution, No. 1, Vol. VIII."

front of it, and is halted by signal when the No. 1 gives the word "fire." The instructor then notes if the gun is correctly laid.

Finding distances by trial shots seems to be brought to perfection in the Prussian service, and should be practised whenever ground can be obtained for the purpose.*

Education has come prominently forward of late years, on account of its extension under school boards to all classes, and also by reason of the alterations of the courses and methods of study now introduced in many schools and colleges. Whilst formerly the memory was chiefly employed in almost all ordinary studies except mathematics, whilst history and geography often consisted of little more than strings of dates and lists of countries and towns committed to memory, the student now-a-days learns fresh subjects—such as chemistry—which exercise the observing and reasoning faculties, and is being taught the old studies in a more intelligent way—as, for instance, in Guyot's Geography, where cause and effect are clearly explained.

The military education of officers of the army has also recently attracted great attention. Doubtless the men also need instruction, especially in the artillery, as the advance in scientific knowledge and manufacturing power of late years has led to numerous improvements in the ordnance, ammunition, and *matériel* employed, and this calls for a corresponding advance in the education and training of the men who use them, in order to develope their full capabilities.

MEAN MEER, PUNJAB,
January 1875.

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* See note on previous page.

ON

ACCIDENTAL EXPLOSIONS.

*A Lecture delivered at the Royal Institution of Great Britain, in March 1875,**

BY

F. A. ABEL, F.R.S.,

President of the Chemical Society, Vice President of the Society of Arts and the Society of Telegraph Engineers, Hon. Member of the Royal Artillery and Royal United Service Institutions, &c.

THE winter of 1874–5 has been unusually prolific in so-called accidental explosions. On Christmas Eve a colliery explosion entailed the sacrifice of seventeen lives, and on one day last January the "Times" published accounts of no less than six fatal explosions—two in collieries, involving the loss of eleven lives; three boiler explosions, by one of which seven persons were killed and twenty injured; and one coal-gas explosion, by which two lives were lost. All these were of the class ordinarily termed accidental, but in every case the casualty was traced to a cause which could have been foreseen and guarded against.

The term "accident," applied in its strict sense to disasters caused by explosions, would imply that these were due to some circumstance, or combination of circumstances, entirely unforeseen, and that they were consequently unpreventable. An explosion which occurs during the preparation or investigation of a compound the explosive nature of which is as yet unknown, may be purely accidental; but if, after the properties of the substance have been thoroughly ascertained and made known, an explosion occurs during its production, by some person who has not properly made himself acquainted with, or has neglected in some point or other, those conditions essential to its production with safety, the knowledge of which is within his reach, the term "accidental" can certainly not be properly applied to it, although in all probability it would be so designated popularly, and even by those entrusted on behalf of the public with the investigation of its origin and results. The explosion occasioned by a person employing a lighted candle to search for a gas-escape in a room where there is a powerful odour of gas, or a gunpowder explosion resulting from the dropping of a spark into an open powder-barrel from a candle which is held over it, should properly have as little claim to be called "accidental" as a boiler explosion occasioned by a person tying down the safety-valve. There may be criminal intent in the latter case, which is entirely absent

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* Reprinted, by permission, from the "Proceedings of the Royal Institution" for 1875.

in the two former, but the probability of an explosion could have been equally foretold in all three instances; and though ignorance may perhaps be pleaded as an excuse in the case of the gas-explosion, and carelessness made to account for that of the powder, those pleas cannot be accepted as grounds for regarding the resulting disasters as legitimate accidents. Indeed, it is often impossible to forbear stigmatising as criminal the carelessness or ignorance which gives rise to explosions of the kind popularly accepted as accidental.

In the present discourse it is proposed to accept the definition "accidental" in the loose sense in which it is popularly applied to explosions, with the object of examining into the nature and causes of such explosions, and, if possible, of indicating directions in which there may be hope of successful efforts being made for reducing the frequency of their occurrence.

The phenomena attendant upon an explosion are generally due to the sudden or very rapid expansion of matter, accompanied in most instances by its change of state from solid or liquid to gas or vapour. The most simple classes of explosions are those caused by the sudden yielding to force, exerted from within, of receptacles in which a gas is imprisoned in a highly compressed condition, or a liquid has been raised to a temperature greatly exceeding that at which its molecules have a tendency to fly asunder or to assume the state of vapour or gas. The strength or elasticity of the envelope which confines them suddenly yielding to pressure, the liquid passes with great rapidity into vapour, violently displacing by this sudden expansion the surrounding air and any other obstacles opposed to the expanding molecules.

Similar explosive effects less simple in their origin are brought about by the sudden development of chemical activity in mixtures of gases or vapours, of solids and gases, or of solids only, or in chemical compounds of unstable character; the result in all such instances being the development of intense heat and the sudden or very rapid and great expansion of matter.

Examples of the most simple class of explosions are the sudden failure in strength at some particular point, or generally, of the material composing a vessel in which a gas has either been liquefied or highly compressed. Accidental explosions of this character take place chiefly, and happily not very frequently, in the laboratory or lecture room, yet instances occasionally occur of disastrous explosions resulting from such causes in manufacturing operations, or in the practical application of compressed air or other gases. The most recent illustration of a serious accidental explosion of this kind is that which occurred in the Arsenal at Woolwich, in January 1874, with the air-chamber of a Whitehead or fish torpedo, when one man lost his life and several were seriously injured. In this instance, some part of the soft steel diaphragm closing the chamber in which the motive power of this self-propellant torpedo (air) was imprisoned under a pressure of about 800 lb. on the square inch, suddenly yielded to the efforts of the gas to return to its normal condition. These air-chambers were invariably tested up to a pressure very considerably exceeding that to which they would be subjected in actual service before they were allowed to form part of the torpedo;

yet in this instance some comparatively weak point in the plate in question, though it had successfully resisted the force exerted by the very highly compressed air for a short period, was eventually tried beyond the limits of its strength by the continued strain exerted by the air confined at a lower pressure; the powers of cohesion of its particles were suddenly overcome, when the confined air, released at one point, expanded with irresistible rapidity, tearing asunder the splendid metal which composed the air-chamber, and consequently inflicting fearful injuries on the poor fellows who were preparing to launch the torpedo on its trial trip. Most careful steps have been taken to avoid the recurrence of an accident of this nature, the possibility of which, with the precautions already adopted, was quite unforeseen.

Other explosions of this class, which are of more than weekly occurrence, and but too frequently result not merely in destruction of property but in more or less serious loss of life, are due to the bursting of boilers at factories, mines, and collieries, to say nothing of those which occur in buildings, in connection with heating appliances and with kitchen ranges, and bath- or other heating arrangements. The explosion of a boiler may arise either from an exceptionally rapid development of steam, the pressure speedily exceeding that which the boiler, or some portion of it, can withstand; or from an absence, or failure in the proper operation, of appliances for relieving the pressure in a boiler, by permitting the escape of steam, and giving warning when the pressure begins to exceed the limit of safety. The suddenly tumultuous evolution of steam may either occur from the boiler becoming overheated in parts, in consequence of the shortness of water, or from the sudden cracking or peeling of a non-conducting incrustation, or fur, on some part of the boiler, whereupon the water comes into contact with the overheated metal beneath it. But by far the chief causes of boiler explosions are defects in their construction or repair, and the reduction in thickness of the metal in parts by corrosion or oxidation, internally and externally, from long use and neglect of proper measures for periodically cleaning the boilers.

The accidents due directly to the deposits formed from water in boilers have been very greatly diminished of late years by the application of preparations called boiler-compositions—of which there are many varieties, their general action being to prevent, more or less effectually, the carbonate and sulphate of calcium and other impurities in water which are separated by its ebullition and evaporation from producing hard impenetrable crusts or coatings upon the inner surfaces of the boiler. The judicious employment of a good anti-fouling preparation, and the thorough periodical cleansing of the interior of boilers, go far to guard against that source of danger; though, in adopting measures to diminish the formation of incrustations, care must also be taken to avoid promoting internal corrosion of the boiler by the agents used.

The operations of the Manchester Steam Users' Association for the Prevention of Steam-boiler Explosions—founded, mainly through the instrumentality of Sir William Fairbairn, twenty years ago, and of which Sir Joseph Whitworth has also been a warm supporter from

its commencement—appear to have gradually succeeded in very importantly reducing the annual number of boiler explosions by introducing among its members a system of periodical independent inspection the efficiency of which is clearly demonstrated by the circumstance that no case of explosion has yet occurred with boilers under the regular inspection of the Association, while between 600 and 800 boilers are examined monthly. The periodical reports prepared by the talented chief engineer of the Association, Mr. Lavington Fletcher, are full of interesting and valuable information, and throw great light upon the chief causes of boiler explosions and the means by which they may be guarded against. The Association will not allow that the term "accidental," or "mysterious," is applicable to steam-boiler explosions. Mysterious they certainly are not, as they are generally quite traceable to causes which may be obviated—such as inferior material, or defective construction, or local injuries, gradually developing and increasing, which would certainly be discovered before they attained dangerous dimensions by a proper inspection; it may therefore not be too harsh to maintain that boiler explosions are not accidental, as their prevention lies in the power of the steam users—though it is true the same view must equally apply to other classes of so-called accidental explosions which are referred to in this discourse.

The following statements, furnished to the speaker by the Steam Users' Association, afford some idea of the number and nature of boiler explosions which have occurred in the last few years. The number of explosions recorded annually by the Association, from 1865 to 1874 inclusive, ranges from forty-eight to seventy-two; the average present annual number is fifty. The largest number of deaths recorded is eighty-seven, and the smallest thirty-two, the present average number being seventy-five. About double that number of persons are seriously injured annually. With respect to the causes of boiler explosions, 40 per cent. were due (from January, 1861, to June, 1870) to malconstruction of the boilers, 29 per cent. to "defective condition" of the boilers, 15 per cent. to the failure of seams of rivets at the bottom of externally fired boilers, 10 per cent. to overheating from shortness of water, and less than 3 per cent. to accumulation of incrustations.*

An examination into the particular nature of the services performed by boilers which have exploded shows that a considerable number of explosions have occurred at iron works, and a very large proportion at collieries, where plain cylindrical externally-fired boilers are much used. Many of the explosions of these particular boilers arise from weak places which remain for a time concealed in the overlaps of the seams of rivets, defying detection, but gradually extending from one rivet-hole to another till some sudden strain causes them to extend throughout the entire seam, the boiler splitting in two. The particular description of boiler which gave rise to the largest number of fatal accidents during the year taken as illustration (1873) was the single-flued or Cornish boiler; and it was stated by Mr. Fletcher that all these explosions

* These data are in part extracted from a table submitted by Mr. Fletcher to the Select Committee on Boiler Explosions, in June, 1870. (*Vide* p. 118 of the Committee's Report.)

must have been the result of glaring neglect, as there is no boiler safer to use when well made and properly cared for. The simple precaution of strengthening, or giving internal support to the sides of the furnace-tube of these boilers, the importance of which was demonstrated many years ago by Sir W. Fairbairn, appears to be still greatly neglected, the result being the frequent collapse of the tube through weakness. This illustration will suffice to indicate the nature of the "defects of construction" which are fruitful of the so-called accidents with boilers. An examination of the details given in Mr. Fletcher's reports as to the cause of explosions reveals a really appalling state of things under the head of "defective condition" of the boilers. In one case the plates are described as having been reduced by corrosion in places to the thickness of paper; in another, they were "in some places not more than from one-thirty-second to one-sixtieth of an inch thick;" in another, they were reduced at the primary rent "to the thickness of a knife-edge;" in another, the plates were in some places "eaten into holes, which were roughly patched by means of bolted cement patches," while many of the rivet-heads were eaten off. These are merely examples of many similar descriptions. Very few explosions in 1873 appear to have been due to the neglect of the attendants, but by far the greater number to that of the boiler owners or the makers. The ignorance or criminal neglect, or worse, which appears occasionally to be displayed in the sale, purchase, and use of second-hand boilers is illustrated by the following two examples:—A boiler which burst in December, 1873, on a rag-puller and waste dealer's premises, scalding three persons to death and injuring five others, was found to have given way on its first trial by its then owners, simply from old age and decay. At the earliest period at which its history could be traced it was purchased second-hand, and worked for five years; it was then left exposed to the weather for five years and afterwards sold to a broker for £5, who re-sold it as old iron for £8. It was then sold for £18 to an engineer, who sold it to its last owners with the assurance that it was safe at a pressure of 60 or 70 lb. to the square inch. The jury at the coroner's inquest returned a verdict of "accidental death," but "desired to express their disapprobation of the conduct of the engineer who sold the boiler as in good working order when the flue-tubes were in some places less than one-sixteenth of an inch thick." The other illustration is that of a large boiler which is graphically described in a professional journal of high standing as having been worked to within an inch of its life, being only removed from its seat because it would hardly hold water. On this boiler there was a patch, more than 2 ft. long, covering a crack of the same length; the patch had only six bolts—three on each side—and was made tight with a piece of old carpet smeared with white lead. Had this boiler burst, the verdict would in all probability have been, as in the other case, "accidental death," though it was worked almost to the last to 35 lb. pressure.

The explosion early in January last of a boiler at North Shields, and of one at Sheffield, affords further illustration, if it were needed, of the fearful danger continually incurred, even by those well acquainted with the properties of iron and steel and the limits of their powers of

resisting strain or pressure, in the employment of boilers long after they had ceased to be trustworthy. At Shields, at a large manufactory of chain cables and anchors, the boiler which exploded had been worked beyond a pressure of 35 lb., while it was unsound, over-patched, and quite unsafe at that pressure. Seven people were killed and about twenty others injured, and a vast amount of property was destroyed, the buildings within 500 yds. appearing as though they had been bombarded. At Sheffield, where the explosion of a boiler not many days afterwards killed two persons, injuring several others, a leakage had been observed in the boiler some time before the explosion, but had not been repaired, and a plate fractured by the explosion had been greatly reduced in thickness by corrosion. This boiler appears to have been worked up to the day of the explosion at a pressure of from 40 to 50 lb., and the workmen employed are stated to have expressed fear at working in its vicinity.

The foregoing and other very numerous illustrations of the appalling display of ignorance, neglect, or recklessness in dealing with the application of steam power, point strongly to the importance of legislation connected with this subject. A Parliamentary Committee of Enquiry reported in July, 1870, that the introduction of compulsory independent inspection of boilers would interfere with the responsibility of the boiler owner; but it is somewhat difficult to realise where the responsibility lies, in the present condition of things. That a system of inspection may be made to work well has been demonstrated by the beneficial results of the now very widely applied labours of the Steam Users' Association; and that Government realises these benefits is demonstrated by the fact that the boilers at the manufacturing establishments of the War Department are subject to the inspection of the Association. There can be no reason why the responsibility of the proper condition of boilers, and steam apparatus generally, should not be thrown upon inspectors, just as the proper fencing of machinery in factories, and the proper condition of steam-boilers in a passenger steam-ship, are secured by a system of responsible official inspection.

The explosions which are often recorded as occurring in kitchen ranges and in boilers used in connection with the heating of buildings are not unfrequently attended by fatal results. Much of what has been said with regard to boiler explosions generally, applies to accidents of this class. Explosions in such boilers have repeatedly arisen from corrosion of the metal, and consequent great reduction of its thickness in places, due to the accumulation of hard incrustations or furs which in time exclude the water from contact with the metal, causing the latter to scale from overheating. The incrustations will crack or split from time to time, in consequence of inequality of expansion or contraction between them and the metal, and if the latter be heated at the time, pressure of steam may be suddenly generated which the worn boiler will not withstand unless provided with an efficient safety-valve.

As the water in kitchen boilers is often used for culinary and drinking purposes, the means employed in boilers used for steam purposes only to prevent the formation of hard deposits cannot be resorted to; therefore the only means of guarding against accidents to

domestic boilers from these causes consists in frequent and thorough cleaning out, which is especially necessary where the water supply is hard.

Explosions also occur with household boilers of the ordinary circulating class, unprovided with safety-valves, through the stop-taps of the pipes which connect them with an overhead cistern being left closed, by accident or negligence, in which case steam pressure must speedily accumulate to a dangerous extent, all outlets being closed. Accidents with such boilers are particularly liable to occur during severe frosts, in consequence of the circulating pipes becoming plugged up with ice, whereby the outlet for steam pressure is as completely cut off as if the stop-taps were closed. Several accidents due to these two causes, some of them attended by fatal results, were recorded last year. The obvious and simple method of guarding effectually against such explosions is to have the boiler fitted with a reliable safety-valve, of the most simple form. A valve of pendulous dead weight construction is specially recommended for this purpose by the Steam Users' Association, as being inexpensive, certain of action, and free from any liability to get out of order. So simple a precaution for avoiding the possibility of a frightful accident surely only requires public attention being directed to it to secure its general adoption.

Explosions resulting from the ignition of mixtures of inflammable gas and air constitute even a more formidable class than that just described; for the number of explosions in coal mines which occur in a year is very considerably greater than that of boiler explosions, while the loss of life occasioned by the former is very considerable, and is occasionally appalling in its magnitude. Thus, in 1871 there were 52 fatal explosions, 268 men being killed, and 234 non-fatal explosions, by which it is estimated that 368 men were injured; and as examples of specially calamitous explosions may be mentioned that at Risca Colliery in 1860, when 142 men were killed, and those at Oaks Colliery in 1866, and Ferndale Colliery in 1867, when 334 and 178 men were killed.

If marsh-gas, or light carburetted hydrogen, which exists imprisoned in coal-beds and escapes into the atmosphere in the pit-working, either gradually or sometimes under considerable pressure, becomes mixed with the air to such an extent that there are about eighteen volumes of the latter to one of the gas, the mixture burns with a pale blue flame, which will surround that of a candle contained in such an atmosphere. The appearance of such a "corpse light" round the flame of the pitman's candle or lamp-flame is a warning—too generally unheeded—of the presence of fire-damp in quantities likely to be dangerous; for if the proportion of marsh-gas increases much beyond that above specified, an explosive atmosphere will be formed, the violent character of which increases as the proportion of fire-damp approaches that of one volume to ten of air. Marsh-gas requires for its ignition to be brought into contact with a body raised to a white heat; fire-damp, or a mixture of marsh-gas and air, is therefore not inflamed by a spark or red-hot wire, but will explode if brought into contact with flame. The

fact that this contact must be of some little duration to ensure the ignition of the fire-damp was applied by Stephenson in the construction of his safety-lamp; and a very philosophical application of the property possessed by good conducting bodies, such as copper or iron, of cooling down a flame below the igniting point of the gas, and thus extinguishing it, was made by Davy in the construction of his safety-lamp.

All the efforts of eminent scientific and practical men, for the better part of a century past, to diminish the number of coal-mine explosions by improving the ventilation of the mines and providing the miner with comparatively safe means of illumination, appear to have had very little effect in reducing the number and disastrous nature of these accidents. Since the construction of safety miners' lamps by Davy, Stephenson, and Clanny, repeated and partially successful efforts have been made to reduce the loss of light consequent upon the necessary enclosure of the flame, and thus to lessen the temptation of the miner to employ a naked flame at his work in fiery mines. Yet investigations after mine explosions still frequently disclose instances of the employment of candles where they are undoubtedly dangerous; and the regulations which have been made law with the view of preventing accidents through the use of naked lights by miners, where there appears any likelihood of fire-damp escaping and lodging, are in many cases either habitually neglected or very carelessly carried out. One practice which appears to have become very general in mines where fire-damp is known to exist—that of sending *firemen* with safety-lamps to examine the mines, the men then proceeding to work with naked lights in all places marked as safe by those officials—is obviously a most dangerous one, the lives of many being made absolutely dependent upon the vigilance and trustworthiness of one or two; yet it appears to be one almost forced upon the managers of collieries by the men themselves, who often absolutely refuse to go to work with safety-lamps. Of the three colliery accidents which occurred between December 23rd and January 7th last, by which twenty-eight men lost their lives, two afford sad illustrations of the fact that the overlookers and the miners themselves are chiefly to blame for the frequency of these accidents, and that the practice of employing "firemen" just referred to is a highly perilous one.

In the case of the explosion at Bignall Hill Colliery, North Staffordshire, the Government Inspector gave evidence to the effect that the explosion occurred in what was admitted to be *the most fiery seam in the North Staffordshire coal-field*, and in which *no naked light ought ever to be used*. The overlooker stated that, having found gas in the heading on the morning of the explosion, he told the men not to go to work there with naked lights; that "he had authority to order lamps, but *he had not done so*, because he had not seen any necessity for it. The explosion might have been avoided if the man whose light was believed to have fired the gas had done his duty and used a lamp." Another witness "had found gas on the morning of the explosion, but not sufficient to lead him to suspect danger. He found gas in the place after the fireman said he had cleared it away; . . . . . the workings always were considered safe, and if he asked a man to use a lamp he would often be laughed at."

The Government Inspector deposed that "all the circumstances went to show that the fireman did not examine the place before the men went to work, and that one of the men walked into it with a naked candle and ignited the gas."

At the second explosion (at the Aldwarke Main Colliery, near Rotherham), the fire-trier appears to have made his customary inspection and found all safe at the place where the explosion occurred, and had left his usual sign to indicate to the men that all was right. The opinion of the engineer was that a considerable fall of roof (of the working) had occurred after he had left, and that, before the liberated gas had time to be carried away by the ventilating current, the men entered and met the gas, which immediately fired. "Had there been a delay, ... or *had the men been provided with safety-lamps*, the accident would in all probability have been averted." In the Report of the accident it is stated that the men in that district will rather leave a colliery than be subject to the strict enforcement of the rules of the Act passed to ensure their safety, and that some such calamity was needed to enforce proper regulations for the safe working of the mine. There can be no question that the comparatively dim light afforded even by the best constructed lamps in general use is the cause of great temptation to the men to use uncovered lights; it is therefore much to be hoped that continued efforts may be made to apply the electric light to the illumination of mine workings. Some approach to success in this direction was already attained ten years ago, and one cannot but have great faith in the ultimate feasibility of some portable method of illumination by electric agency.

There are, however, causes other than the use of unprotected lights which contribute to the production of coal-mine explosions. Efficient ventilation of workings, whether in use or not, whereby all dangerous accumulation of fire-damp is avoided and any sudden eruption of gas may be rapidly dealt with (the gas being largely diluted and swept away as speedily as possible) is indispensable to the safe working of the mine (without any reference to the health of the men) so long as there is any temptation for the use of naked lights. The original laying out of a working greatly affects the question of efficient ventilation, and explosions have been clearly traced to gas accumulations which there was sufficient power of ventilation to reduce if the nature of the working had admitted of its proper application. At the Bignall Hill Colliery, where the fearful explosion occurred on Christmas Eve last, the ventilation had been reported imperfect about three weeks before the accident, and the Government Inspector stated that the deficient ventilation was due to the improper laying out of the work. In arranging for the efficient ventilation of a mine, ample provision for rapidly applying extra artificial ventilating power should be made; and in connection with this the interesting and useful series of observations should be borne in mind which have been made public in communications to the Royal Society and the Meteorological Society by Messrs. R. H. Scott and W. Galloway. Those gentlemen have clearly established a connection between the occurrence of meteorological changes and colliery explosions; they have shown that explosions

frequently occur at the time of considerable barometric disturbances, which must unquestionably affect the rate of diffusion of the fire-damp into air and the rapidity of air circulation in a mine. They also point out that when the external temperature rises very considerably, the natural ventilation, due to the higher temperature of the air in a mine, is liable to cease, by the external atmospheric temperature becoming equal to, or perhaps exceeding, that in the mine. They consider that of 233 explosions which occurred in 1872, 58 per cent. were due to disturbances of atmospheric pressure, and 16 per cent. to excessive heat of the weather; and they have similarly traced the proportion in which the same meteorological changes have contributed to bring about explosions in other years.*

Since the employment of gunpowder as a means of rapidly removing coal, or overlying shale, has come into considerable use, there can be no question that an additional and a very serious source of danger has been imported into the working of collieries. That the explosion of a charge of powder in a blast-hole, or the "firing of a shot," has by no means unfrequently resulted in the production of a fire-damp explosion, has been clearly established by careful enquiry. This has been ascribed to two causes—one of them the direct ignition of the explosive gas-mixture by the flame from the shot, the other the dislodgment of fire-damp from cavities or disused workings by the concussion produced, and its ignition by some naked flame or defective lamp in the neighbourhood. If a shot takes effect properly (*i.e.*, if the force is fully expended in breaking the coal or rock at the seat of the charge), there is seldom flame produced; but if the tamping which confines the charge in the blast-hole is simply blown out of the latter like a shot from a gun (which not unfrequently occurs when the rock is very hard or the tamping is not sufficiently firm, or when the charge of powder is excessive), the powder-gas issuing from the blast-hole will produce a flash of fire as obtained with a gun; and if the fire-damp were in the immediate neighbourhood, it would no doubt be ignited thereby. But this combination of conditions is not likely frequently to occur; the second cause above given is therefore more likely to be fruitful of accidents: but the existence of a third cause, to which the majority of explosions connected with blasting in collieries is most probably ascribable, has been very clearly established by the careful enquiries,

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* Reference must be made here to an ingenious application, made by Mr. Ansell, of the laws of diffusion and osmose for detecting the presence of fire-damp in coal-pits. Two or three forms have been given by Mr. Ansell to the detector apparatus; perhaps the most simple consists of a ball of thin india-rubber, filled with air and fixed upon a stand under a lever which slightly presses the upper surface of the ball. If from any cause the lever is raised, it liberates a spring which sets a bell in vibration, or brings an electro-magnetic alarum arrangement into operation. If this apparatus is placed where fire-damp exists to an important extent, the light carburetted hydrogen passes through the pores of the india-rubber ball, and as the air in the latter passes outwards at a much lower rate, the ball soon distends, exerting sufficient pressure on the lever to bring into action the signalling arrangement, which, if electric, may be placed at any convenient distance from the fire-damp detector, being connected with the lever by means of conducting wires. It would appear as though a detector of this nature could be made of important service in fiery mines; but its employment does not seem as yet to have passed beyond the experimental stage.

sound reasoning, and ingenious experiments of Mr. W. Galloway, Inspector of Mines. The fact has long been known that if an explosive gas-mixture be driven, in a current of sufficient force, through the gauze of a safety-lamp at right angles to the lamp, flame may be forced through the meshes, and may thus ignite the explosive mixture outside the lamp; but Mr. Galloway conceived, and has clearly established by experiments in the laboratory and in coal-pits, that the sound-wave established by the firing of a shot (especially by the sharp explosion produced when the tamping is shot out of a hole) will by transmission, even to very considerable distances, have the effect of forcing flame through the meshes of the gauze of a safety-lamp, and will thus lead to the ignition of an explosive gas-mixture surrounding the latter. Safety-lamps may frequently be accidentally surrounded by (or purposely introduced, for purposes of inspection, into) an explosive atmosphere at the time that shots are fired in neighbouring workings; and the circumstantial evidence collected after the occurrence of some explosions has undoubtedly indicated that this is the most probable explanation of the cause of the accident. It is probably not to be expected that even in fiery coal-pits miners will forego the advantages derivable from the employment of gunpowder, and it appears next to impossible to enforce prohibitory regulations with respect to such pits; but it may perhaps at any rate be hoped that the miner may be trained to a knowledge of the danger he incurs by the incautious use of gunpowder, although the persistent recklessness with which he sacrifices safety to comfort, in despising the use of the safety-lamp, forbids sanguine expectations in this direction.

Reference has not been made to another very possible source of accidents, due to the employment of gunpowder for blasting purposes—namely, carelessness in the keeping and handling of the explosive agent by the men. Personal observation by the speaker of the reckless manner in which powder is frequently dealt with in mines, leads him to believe that this contributes its quota as a cause of colliery explosions.

The accidents in collieries have their parallel in domestic life in coal-gas explosions, which, though at first sight of comparatively small importance, if judged by the loss of life and property which they occasion, yet merit serious consideration on account of the great frequency of their occurrence, and the demonstration which they almost always afford of ignorance or culpable carelessness. Whether occasioned by defective gas-fittings or by want of care in dealing with the gas-supply, the escape of gas in a confined space, in any but very small quantities, must speedily result in the production of an explosive gas-mixture, by the rapidity with which the gas will diffuse itself through the atmospheric air surrounding the point of escape. The application of flame to such a mixture must inevitably result in an explosion, the destructive effect of which is regulated by the quantity of gas escaping and the time which it has had to mix with the air.

The circumstance that the admixture of even minute quantities of coal-gas with air can be at once detected by the unmistakable odour of the gas, should serve as a safeguard against accidents; unfortunately,

however, thoughtlessness or want of knowledge frequently causes this very fact to lead to the opposite result. Escapes of gas in comparatively small quantities often occur at the point of union (generally by a ball-and-socket joint) of a hanging burner or chandelier with the gas-pipe, or at the telescope-joint of such gas-fittings; the column of water required in the joints to confine the gas becoming very gradually reduced by evaporation. In such instances an explosive mixture will accumulate in the upper part of an apartment of which windows and doors are closed, while the air in the lower part will continue for a long time free from any dangerous admixture of gas. Instances are continually recorded in the public prints of the deliberate ignition of such explosive mixtures by persons who, observing the smell of coal-gas upon entering the room, proceed forthwith to search for the point of escape by means of a flame. It need scarcely be stated that such a test is a perfectly safe one in itself, and that if the acceptance of the warning given by the odour of gas in the lower part of the room were promptly followed by the simple precautionary operation of leaving open for some time all windows and doors, so as to afford ready ingress of fresh air, and thus speedily expel, or very largely dilute, the gas-mixture, the leakage could be looked for with no risk of accident.

Gas explosions, generally of a serious nature, do occasionally occur through no fault of those who are the direct agents in bringing them about—as by a person entering with a light a closed apartment in which there has been a very considerable escape of gas for some time, or a building into which gas has been entering from a leakage in the supply-pipe or the main. A very sad accident of the latter kind occurred in January last at Durham, resulting in the death of two persons. The occupants of a house had noticed on a Saturday afternoon a smell of gas, which was traced to a leakage in the main-pipe by the gas company's servants, who stated that it could not be repaired until the following Monday. The man, being satisfied that the gas-escape did not occur in his house, lighted a candle some time afterwards, with the result that a terrific explosion nearly wrecked the house, which had become to a very considerable extent filled with explosive gas-mixture. In another recent instance, the accidental ignition of an explosive coal-gas mixture issuing from a drain-pipe communicating to the sewer in which gas had leaked from the main, caused the demolition of one house and the partial destruction of another, the inmates, in both instances, escaping fortunately, though with bad injuries. The first of these accidents, at any rate, would not have occurred if prompt means had been taken for stopping the leakage when its source was discovered; and it may be confidently affirmed that a very large majority of the accidents resulting from coal-gas explosions might be avoided by the exercise of ordinary care and intelligence.

The employment of illuminating agents closely allied to coal-gas—namely, liquid carbo-hydrogen compounds obtained by the distillation of coal or shale, or derived as natural products from coal-bearing strata, gradually extended during the earlier part of the last quarter of a century until they became formidable rivals of mineral and vegitable

oils and even of gas itself. Among the very earliest of these so-called mineral oils was paraffin oil, first obtained from a particular description of schist or coal, by Mr. Young; but some time before then, the most volatile products obtained by the distillation of coal-tar were employed in lamps without wicks, of such construction that the volatile liquid, flowing by gravitation from the reservoir to the source of heat, was converted into vapour as it reached the point where the jets of flame were produced. The great facility with which the more volatile portions of rock-oil or petroleum, and of the products of distillation from coal and schist, were applicable as brilliant illuminating agents in lamps of simple, cheap, and convenient construction, combined with the low price at which they could be retailed, consequent upon the great development of the petroleum industry in America, soon led to their extensive employment by the general public, and the importation of these volatile oils or spirits attained in a short time a scale of considerable magnitude.

The several varieties of so-called petroleum spirit which are known as naphtha, benzine, benzoline, gasoline, japanner's spirit, &c., yield vapour more or less freely on exposure to air at ordinary atmospheric temperatures, and even in some cases below 50° Fahr. Their low specific gravity and volatility permit of their employment in very simple and inexpensive lamps—the commonest form now extensively used by the poorer classes all over the country being the "sponge lamp," in which a small strip of sponge or coarsely plaited wick serves the purpose of drawing the spirit up from the reservoir to the orifice, where it is vaporised and burned. Although much the largest proportion of the petroleum spirit employed is probably used in lamps of some form or other, there are additional important uses to which it is applied in large quantities—*e.g.*, as a detergent, by dyers, &c.; as a substitute for turpentine in paints and varnishes; as a means of imparting luminosity to non-luminous inflammable gas, or of rendering atmospheric air itself the vehicle for illumination by saturating it with benzoline vapour; as a solvent and purifying agent in connection with the manufacture of artificial alizarine, &c.

The statistics of the imports into London and Liverpool during the last three years show a very considerable increase in the consumption of petroleum spirit, as will be seen from the following numbers:—

	1872.	1873.	1874.	
Barrels imported ...	33,693	45,889	58,687	London.
	26,871	27,394	47,200	Liverpool.

The imports of the less volatile and properly refined petroleum products, known generally as petroleum oil (also called kerosine, crystal oil, rock oil, astral oil, and, incorrectly, paraffin oil), which do not yield vapour below a temperature of 100° Fahr., have fluctuated considerably during the last six years, but have increased lately to about five-fold into London, and four-fold into Liverpool, of what they were in 1872, as shown by the following numbers:—

	1872.	1873.	1874.	
Barrels imported ...	48,295	206,573	245,291	London.
	46,679	104,155	159,700	Liverpool.

The so-called paraffin- or petroleum-lamp *explosions*, of which in the

earlier days of the employment of these illuminating agents there were so many recorded in the newspapers, and of which one still hears occasionally, were, with very few exceptions, not correctly designated as explosions, and when they were so, were not caused by the employment of the volatile oils or petroleum spirit. As these vaporise very freely at the slightly elevated temperature which a reservoir of a lamp soon attains, air is either entirely expelled from the latter by the vapour, or so diluted by it that the mixture is not explosive. If, therefore, flame can have access to vapour escaping from any opening in the reservoir near the wick, in a badly-constructed lamp, it will merely burn as it escapes. If a lamp charged with petroleum spirit be carried incautiously, or accidentally jerked so that the liquid is suddenly brought into contact with the warmer portion of the lamp, near the flame, a very rapid volatilisation may thereby be caused, resulting in a considerable outburst of flame. In either case, a nervous person, holding the lamp at the time, may drop it in alarm, or the reservoir, if of glass, may be broken by the sudden burst of vapour and the resulting large flame; in such instances, the spirit will be scattered and at once inflamed, inflicting injuries more or less severe on the instigator of the accident, or setting fire to the premises.* A so-called petroleum-lamp explosion which occurred, quite recently, at Gloucester, resulting in the death, from burns, of a woman, was evidently brought about by the cause last described.

If a petroleum oil which has been imperfectly refined, and which therefore contains some proportion of the very volatile products, or spirit, be employed in a lamp, a slight explosion may be caused by its yielding up a small amount of vapour at the temperature to which the reservoir becomes heated, and thus producing a feebly explosive mixture with the air in the latter, which may become ignited by the flame of the lamp. An explosion thus produced is not at all of violent character, being generally merely a feeble puff; it may, however, cause the cracking of the reservoir, and the consequent spilling and inflaming of the oil, and may at any rate lead to accident as already described, by the alarm which it occasions to nervous or ignorant persons.

There is no doubt whatever that a very considerable proportion of the accidents which occur to persons using petroleum lamps are really traceable to the erroneous belief, which is still so very prevalent, in the *explosive* character of these liquids. The fact that they and their vapours are simply inflammable, and that the latter require to be mixed with a

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* The Reports by Captain Shaw to the Metropolitan Board of Works of the causes of fires in London, show a generally steady increase in the number of fires caused by lamps. Thus, there were 20 in 1866, 30 in 1869, 49 in 1871, 56 in 1872, 47 in 1873, and 67 in 1874. These returns include fires from lamps of all kinds (many not defined); but it may be reasonably assumed that three-fourths of the totals noted were caused by petroleum-lamps. From one to seven fires annually are reported as caused by upsetting, "drawing off," or explosion of naphtha, paraffin, crystal oil, or petroleum. The proportion which fires from the above causes bear to fires caused by candles is small, but has been on the increase in the last few years. From 1866 to 1870 inclusive, the fires caused by candles were from seven to ten times more numerous than those caused by lamps; but in 1872 they were only about five times; in 1872 and 1873, four times; and in 1874 only a little over three times more numerous.

large volume of air before their ignition can be accompanied by explosive effects, is so slowly realised, that in public prints petroleum is still often spoken of as an explosive substance, although these very prints have recorded such events as the *burning*, in 1866, of warehouses at Bow containing 1000 barrels of petroleum, besides four barges laden with petroleum lying alongside the wharf, without any explosion; and the ignition at New Jersey (in August, 1874) of a petroleum tank in the Erie Railway Company's oil-yard, and the consequent *burning* of 70,000 barrels of petroleum. The popular belief in the explosiveness of these simply inflammable liquids contrasts strangely with the fact that many explosions have been brought about by the careless employment of candles or other naked flames in premises where the volatile varieties have been stored, or where the operation of transferring the liquid from one vessel to another for purposes of sale is carried on, the result being the ignition of the explosive mixture *produced* by the volatilisation of the spirit and its diffusion through the air. This fact does indeed tend to discourage the hope that the proportion of accidental explosions of *gunpowder* which are apparently due to ignorance may become very greatly diminished by keeping its explosive properties before the minds of those using it.

Although those petroleum accidents which are the results of carelessness or ignorance are very difficult to attack, the community has unquestionably benefited very considerably in the matter of optional comparative security by the legislation of the last few years in connection with the storage and sale of petroleum, imperfect though it still is. The prohibition of the sale of petroleum spirit of any kind, unless distinctly labelled so that the public may be alive to its specially dangerous nature as a very volatile liquid, and the limitation of its storage and sale, by properly licensed persons, to localities specially selected and inspected by responsible officials, have most certainly contributed greatly to the protection of the public against accidents entailed by the use of these materials. A still more important benefit which has resulted from legislation on this subject, aided by the zealous action of the Petroleum Association and of municipal authorities, is the almost complete exclusion from the market of such petroleum *oil* as yields inflammable vapour at temperatures considerably above the maximum atmospheric temperatures of Great Britain. The danger arising more especially from the transport and storage of oils bearing names which apply to the properly refined and therefore safe petroleum- or coal-oils which do not demand special precautions for their safe storage and use, and are consequently not subject to any restrictive or precautionary regulations, renders the application of the existing legal regulations to the inspection of petroleum *oils* imported into England of special importance. Such inspection, if efficiently conducted, must afford important protection to consumers and communities, by maintaining strictly the line of demarcation which it has been the object of legislation to establish between very volatile and therefore highly inflammable petroleum- or coal-products and those liquid hydro-carbons of the same origin which are comparatively very safe illuminating materials, because they do not evolve vapour at any temperature below

about 100° Fahr. A thoroughly trustworthy and sufficiently simple method of testing the oils is essential to the attainment of this result; and after much consideration and practical experience had been brought to bear on this subject, the so-called *flashing test* described in the Act of Parliament, was adopted as the fairest and most reliable one which could be prescribed for general application; but there is no doubt that, when applied to oils which nearly approach in their flashing point the limit prescribed by the Act, the operation of the test is not sufficiently sharp, nor the prescribed method of conducting it sufficiently rigid, to preclude the possibility of its furnishing conflicting results in different hands, and thus leading to decisions the justness of which may be legitimately open to dispute. It is therefore undoubtedly desirable, in the framing of any future Act, that this test should be carefully reconsidered, as well as the question whether some narrow limit below 100° Fahr. may not reasonably, and without incurring any increased risk, be fixed within which the flashing point of an oil (*i.e.*, the temperature at which it evolves vapour) may range.*

Such accidents as the explosion of a mixture of petroleum vapour and air in a ship on the Thames (the "Maria Lee"), laden with about 300 barrels of petroleum and with other inflammable materials (in June, 1873), followed by her complete destruction by fire, in somewhat alarming proximity to the Purfleet powder magazines, and a similar accident in Glasgow Harbour, demonstrate the importance of the regulations which are imposed by the local harbour authorities, as directed by the existing Act of Parliament, upon all ships carrying petroleum spirit, with respect to their mooring and the landing of their cargo. The Act also gives to the municipal and other licensing authorities the very important power of including, as conditions of the licenses, regulations with regard to the quantity of petroleum spirit to be stored in a particular locality, the nature and situation of the store with reference to inhabited buildings, the mode of storage, and the nature of the other goods to be stored with it. Very efficient regulations have consequently been adopted by the Metropolitan Board of Works, and some other local governing authorities, with regard to the stores themselves, the exclusion of any source of fire or artificial light from them, the nature of the receptacles in which the petroleum is kept, &c. The latter is a point of the utmost importance, as specially affecting the risk of accident in storing and *transporting* petroleum spirit, and one which it is very necessary that legislation should deal with more specifically than is at present the case. The existing Act specifies that limited quantities, for sale or consumption, may be kept without a licence, provided they are contained in small vessels of glass, earthenware, or metal; but it is silent on the subject of the vessels in which larger quantities are to be stored, or with respect to any regulations conducive to safety in the transport of petroleum spirit. As

* As the law at present stands, an oil the flashing point of which is declared to be 99° by the official inspector, must be condemned; but another operator may make the flashing point of the same oil to be slightly above 100°. Practically, an oil with a flashing point of 97° or 98° would be quite as safe as one which answers to the test at 100°, in the hands of the same operator.

regards the first point, it certainly gives ample power to licensing authorities; but that legislation is urgently needed in regard to the second, was demonstrated by the recent fearful catastrophe on the Grand Junction Canal.

The liability of oil or spirit to leak from casks or barrels, even of the best construction, consequent upon the rough usage to which these are unavoidably subjected when transferred from store to ship or carriage, and the reverse, need scarcely be pointed out. But even in the absence of leakage from the openings of the barrels, or from any accidental point of escape, evaporation or diffusion of the volatile petroleum will occur through the wood itself of which they are constructed, especially in the warm holds of ships or in stores exposed to the sun, even though the precautionary measure is frequently adopted of rinsing the barrel out before use with a solution of glue. It is evident that the object of imparting an impervious coating to the interior of the barrel can thus be only very imperfectly attained, and that, even if it were, the alternations of temperature to which the barrels must be exposed must in course of time open up places for escape by leakage or evaporation.

It is stated, on the authority of the manager of the extensive depôt for petroleum oil and spirit of the London Wharfing and Warehousing Company, at Plaistow, on the Thames, that in spite of the adoption of special arrangements for keeping down the temperature of the petroleum-spirit stores, whereby it is made not to exceed 62° Fahr. in the very hottest weather, the loss of spirit by leakage and evaporation is very considerable, amounting to an average of 18 per cent. As the loss on petroleum *oil* from leakage at the same establishment amounts to about 9 per cent., it is evident that the limpidity and volatility of the spirit give rise to a loss as great again as that which is simply due to leakage from imperfectly closed vents or defects developed by rough usage.

The dangers resulting from the escape of petroleum spirit or its vapour from receptacles in which it is kept, in confined spaces, where little or no ventilation exists, has been but too frequently exemplified by explosions more or less violent, followed by fires, in localities where it is stored or handled, or in the holds of vessels in which it is transported. Accidents of such kinds have been due either to carelessness in transferring petroleum from one vessel to another, in a shop or store in which a light has been burning at the time, or to a light being carried into, or a match struck in, a store where vapour has been escaping until it has formed an explosive mixture with the air. The explosion which occurred in a sewer at Greenwich last January, and was productive of much damage, was clearly traced to the entrance into the sewer of certain petroleum products (from a patent gas factory in the neighbourhood); the vapour from these had formed an explosive mixture with the air, which had become accidentally lighted—perhaps by the dropping of an inflamed pipe-light through one of the sewer-gratings. The speaker has a vivid recollection of an accident of this kind which he witnessed at the Royal College of Chemistry in 1847. Mr. C. B. Mansfield, who was then engaged in his important researches on the composition of coal-tar naphtha, which led a few

years afterwards to his sad untimely death, was engaged at one extremity of a low room (38 ft. long, about 30 ft. wide, and 10 ft. high) in converting one of the most important of these products—benzol—(which boils at 176° Fahr.) into nitrobenzol in a capacious retort, which suddenly cracked, and, yielding to the pressure of its contents, allowed the warm liquid hydro-carbon to flow over the operating table. There was a gas-flame burning at the other extremity of the laboratory and no other source of fire. Within a very few minutes after the fracture of the vessel a sheet of flame flashed from the gas-flame along the upper part of the room and communicated to the table upon which the liquid had been spilled.

The firing of the ship "Maria Lee" just now referred to was clearly proved to have been preceded by the explosion of a mixture of air and petroleum-vapour, produced by leakage or evaporation from the barrels stored in the hold of the vessel. The weather was very hot at the time, and, there having been a heavy thunderstorm the night before the fire, the hatches had been kept closed and covered over with tarpaulin, so that there was no possibility of ventilation. The vapour gradually diffused itself through the air in the ship during the night until the explosive mixture extended to the cabin at the after part. As the captain entered this cabin quite early in the morning (the *immediate* source of the fire was not clearly traced) a loud explosion occurred, and flame was immediately observed issuing from the fore part of the ship.

A similar explosion of petroleum-vapour and air occurred not long since in a ship at Glasgow; and, lastly, it was established by a sound chain of circumstantial evidence that the explosion of the powder-laden barge in the Regent's Park must have been caused by the ignition, in the cabin of the barge, of an explosive mixture of air and of the vapour of petroleum, derived from the leakage of certain packages of the spirit which were packed along with the powder. The description given by an eye-witness, on board a barge in front of the ill-fated "Tilbury," of a bluish flash of flame, emanating from the cabin of the barge within a very brief period of the explosion, corresponds with the result produced when flame is applied to a mixture of hydro-carbon vapour with a large proportion of air. The manner in which the freight of the barge was enclosed by tarpaulins precluded ventilation, and was most favourable to the gradual diffusion of inflammable vapour, from even slight leakages in the barrels, through the confined air, until an explosive mixture extended to the opening in the bulk-head or partition, which in these barges separates the cabin from the hold.

It is impossible to protect heavy packages from rough usage, in the processes of unloading ships or other vehicles of conveyance; it is therefore most important that means should be adopted of thoroughly closing the vents of receptacles of petroleum spirit, by such means as are capable of sustaining ordinary rough usage without any injury to their efficiency, and that the improvement of the nature and construction of the receptacles themselves should be seriously considered, with the view of reducing the liability to accidents resulting from the escape of the spirit or its vapours, and the consequent creation of danger connected with the transport and storage of these valuable illuminating materials.

The fact that combustible, and especially inflammable solid substances, if of sufficiently low specific gravity, and reduced to a sufficiently fine state of division to allow of their becoming and remaining for a time suspended in air, may furnish mixtures with the latter which partake of explosive character, scarcely needs to be pointed out. The ignition of a particle of such a substance, surrounded by atmospheric oxygen, will, under these conditions, at once communicate to others immediately adjacent to it; and if the particles of suspended solid matter be sufficiently numerous and finely divided, the ignition will spread throughout the mixture with a rapidity approaching that of a mixture of inflammable vapour and air, the development of gaseous products and heat being sufficiently rapid and considerable to produce explosive effects, which may even be of violent character, their violence being regulated by the nature and *inflammability* of the solid substance, the proportion and state of division in which it is distributed through the air, the quantity of the mixture, and the extent of its confinement.

Explosions of an accidental nature produced in this way are believed to have occurred in connection with operations in the chemical laboratory; but it was scarcely to be expected that the first clearly authenticated cases of any importance should have arisen out of the apparently harmless operation of grinding corn.

That a mixture of very fine flour and air will ignite with a flash when light is applied to it, and produce in a very mild form the species of explosion observed on applying a light to lycopodium suspended in air, is not very difficult of demonstration; but it is not easy to realise the possibility of the production of violent explosive effects by the ignition of such a mixture, even upon a very large scale, though the rapidity of its ignition be accidentally favoured by the warmth of the atmosphere. Cotton mills have been known to be rapidly fired by the ignition of cotton particles suspended in the air; but, compared with flour, cotton is very combustible. Flour, when absolutely dry, would contain only about half its weight of carbon, and about 6 per cent. of hydrogen; the remainder consisting of nitrogen and mineral substances—constituents which, by absorbing heat instead of contributing to its development, must tend to reduce the rapid combustibility of the substance. Yet the possibility of very serious calamities arising out of the accidental ignition of a mixture of flour-dust and air has been but too conclusively demonstrated.

On the 9th July, 1872, the inhabitants of Glasgow were startled by an explosion which was heard to a considerable distance, and occurred in some very extensive steam flour-mills, of which the front and back walls were blown out, while the interior was reduced to ruins, and speedily enveloped in flame, destroying the remainder of the extensive buildings. Several persons were killed, and a number of others were severely burned, or injured by the fall of masonry. That the explosion was not occasioned by the steam-boilers employed as motive power in the mill was soon made clear; and by the evidence of persons employed in the mill at the time of the explosion, its origin was conclusively traced to the striking of fire by a pair of millstones, through the stopping of the "feed," or supply of grain to them, and the consequent friction of their bare sur-

faces against each other, the result being the ignition of the mixture of air and fine flour-dust surrounding the millstones.

This ignition alone would not suffice to develop any violent explosive effects; such ignitions, though occasionally observed in small mills, being caused either by the striking of fire by the stones, or by the incautious application of a light near the millstones, or the meal-spout attached thereto, have not in these instances been attended by any serious results. But in an extensive mill, where many pairs of stones may be at work at one time, each pair has a conduit attached to it, which leads to a common receptacle called an exhaust-box; into this the mixture of air and very fine flour-dust which surrounds the millstones is drawn by means of an exhaust-fan, sometimes aided by a system of air-blowers. The fine flour is allowed to deposit partially in this chamber or exhaust-box, and the air then passes into a second chamber, called a stive room, where a further quantity of dust is deposited. It follows that when the mill is at work, these chambers and the channels or spouts connecting them with the atmosphere immediately surrounding each millstone, are all filled with an inflammable mixture of the finest flour-dust and air, and that consequently the application of a light to any one of those channels, or the striking of fire by any one of the millstones, by igniting some portion of the inflammable mixture, will result in the exceedingly rapid spread of flame throughout the confined spaces which are charged with it, and will thus develop an explosion. The violence of such explosions depends much upon details of construction of the exhaust-boxes and stive rooms, and upon the dimensions of the channels of communication; it must obviously be regulated by the volume of inflammable mixture through which fire rapidly spreads, and upon the extent of its confinement. In the case of the catastrophe at Glasgow, the production of a blaze at a pair of millstones was observed to be followed by a crackling noise as the flame rapidly spread through the conduits leading to the exhaust-box upon an upper floor, and a loud report from that direction was almost immediately heard. Professors Rankine and Macadam, who carefully investigated the cause of this accident, report that other flour-mill explosions which they have enquired into had been observed to be attended by a similar succession of phenomena to those noticed upon this occasion. The bursting open of the exhaust-box by a similar though less violent explosion, attended by injury of workmen, the blowing out of windows and loosening of tiles, appears to have taken place on a previous occasion at these particular mills. In the last accident, however, the more violent explosion appears to have been followed by others, the flame having spread with great rapidity to distant parts of the mills through the many channels of communication in which the air was charged with inflammable dust, resulting from the cleansing and sifting operations carried on in different parts of the building, and rapidly diffused through the air by the shock and blast of the first explosion.

The subject of flour-mill explosions, though it has attracted little if any attention in this country previous to the Tradeston explosion, is discussed in Continental treatises on flour-mills, and the results of Messrs. Rankine and Macadam's enquiries have demonstrated that accidents of this kind are actually of ordinary occurrence in mills,

especially since the introduction of the exhaust arrangements. Those gentlemen point out that it appears scarcely possible to guard against such accidents altogether, although the frequency of their occurrence may probably be much reduced by adopting efficient precautions to prevent, as far as possible, a stoppage of the "feed" to the millstones or the accidental introduction of nails between them together with the grain, and by prohibiting the employment of naked lights in the vicinity of the mills and the dust passages. In order to reduce as far as possible the damage and risk of sacrifice of life resulting from such explosions, it is important that all receptacles into which the dust-laden air is drawn from the mills should be fixed outside the buildings, and constructed so as to offer as little resistance as possible to the sudden expansion resulting from the ignition of the inflammable mixture. The conduits leading from the mills to the exhaust-chambers should, moreover, be of small dimensions, and there should be no other communication between the interior of the building and the dust receptacles, which must not be opened while the mill is at work. By adopting precautions of this kind, the mill-owner may succeed, at any rate, in reducing the mischief resulting from an accidental ignition of flour-dust at the millstones to such limits that the mill itself and the lives of those engaged in it will not be endangered.

The production of explosions by mixtures of air with marsh-gas, coal-gas, petroleum vapours, or a finely divided inflammable solid, such as flour, has been shown to be due to the application of sufficient heat to some portion of the mixture to cause the atmospheric oxygen to combine with the combustible constituents of the gas, vapour, or solid, the results being the development of chemical action, the formation of gaseous products, and their expansion by the heat developed. It need scarcely be said that the same explanation applies to the production of explosions by that class of so-called explosive agents which is prepared by intimately mixing combustible or inflammable solids with a solid oxidising agent (*i.e.*, an oxygen-compound which readily yields up a part or the whole of that gas under the influence of heat, and with the co-operation of chemical force, to carbon, hydrogen, or other readily oxidisable elements). Distinct from these explosive mixtures as regards their nature, but quite analogous to them in their behaviour and the effects they produce when subjected to heat or other disturbing influences, are explosive *compounds*. The majority of these contain carbon, hydrogen, and oxygen as the most important components; they are more or less susceptible of sudden or extremely rapid transformation into gases or vapours, attended by development of great heat, in consequence either of their resolution into their elementary constituents, or, generally, of the re-arrangement of these into comparatively simple forms of combination. Some of these explosive compounds are of such unstable character, that they are liable to undergo change from very slight inciting causes—such as the existence in them of minute quantities of foreign substances of active chemical character; or they may even be prone to absolutely spontaneous change. In such substances decomposition may be in the first instance established only to a very minute extent; but this decomposition, by the products to which it gives rise, and by the attendant development of heat, however small, may speedily promote further and

more rapid change in the mass of the substance, so that eventually decomposition of violent nature may be established, and the principal portion of the compound may suddenly undergo the same transformation into gases or vapours, attended by the same development of heat, as though any one of the agencies (*i.e.*, fire, friction, or percussion) ordinarily employed to determine the explosion of these bodies had been applied. Cases of so-called spontaneous explosion thus brought about are more familiar to scientific and manufacturing chemists than to the general public; but accidental explosions of very alarming and, in a few instances, of very calamitous character are on record which, though not actually of spontaneous nature, in the strict application of the term, have been brought about without any apparent application of external inciting agencies, and have hence, from a practical point of view, not been incorrectly classed as spontaneous explosions.

A few substances, well known to chemists, are so very unstable in character, or are so very difficult to prepare in a condition approaching purity, that they either begin to undergo change as soon as they have been produced, or very shortly afterwards; such change proceeding sometimes gradually and quietly until the substance has been transformed into non-explosive bodies, or occurring, in other instances, with a rapidity speedily resulting in the violent decomposition or explosion of the substance. Injuries more or less severe have been inflicted upon the discoverers or investigators of substances of this kind, or upon those who prepare them and exhibit their properties for instructional purposes; and such accidents occasionally occur, even though all possible or reasonable precautions appear to have been taken to guard against them. It has occasionally also happened that serious accidents have resulted from attempts to apply to practical purposes the explosive power of such substances (as, for example, the chloride of nitrogen and iodide of nitrogen), by persons imperfectly acquainted with their properties or those of explosive substances generally. The great danger in which want of knowledge may involve experimenters in this direction is too obvious to need being dwelt upon.*

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* The great danger incurred in experimenting with, or attempting the manufacture upon a large scale of, substances of unstable and explosive nature the properties of which are imperfectly understood, has been exemplified by repeated accidents with a liquid called methylic nitrate, the vapour of which is highly explosive. In 1872, a young English chemist of great promise lost his life by a very violent explosion which occurred in a laboratory in Germany, where he had been engaged in preparing large quantities of this substance with a view to its employment as a substitute for nitroglycerine preparations. No conjecture could be formed of the immediate cause of the explosion. Some time after, a German manufacturing chemist of eminence lost the sight of one eye by the violent explosion of a very small quantity of the same substance while he was heating it in a glass tube; and in November last a very violent explosion occurred at the works of a manufactory of dyes at St. Denis, in a building where very considerable quantities of the methylic nitrate were being prepared and purified for colour-making purposes. Two men were killed, and a number seriously injured. In this case the accident was clearly traced to an act of recklessness of one of the workmen. The use of lights was prohibited in the building where the purification of the substance was carried on, in consequence of the inflammable vapour evolved and the danger of explosion from its ignition; but on this occasion a man not only brought a lamp into the room, but actually lowered it into a large boiler from which the liquid was being decanted with a siphon—his object being to see how much remained. The vapour in the boiler was at once fired, and a violent explosion occurred almost immediately, followed by a second—there being upwards of 1000 lb. of the material in an adjoining store.

The risk of accident resulting from the liability of explosive compounds to so-called spontaneous decomposition has been on several occasions exemplified in the past history of the two most important of these compounds—gun-cotton and nitroglycerine. Until within the last few years, it was believed that both these substances were in themselves so prone to change that their preservation for any length of time without undergoing spontaneous decomposition, resulting most probably in explosion, was regarded as, at best, a great uncertainty. They acquired this character for instability partly from the imperfect purification of specimens prepared from time to time for scientific or instructional purposes, and partly from repeated attempts to utilise their explosive properties, and therefore to produce them in considerable quantities, while their nature and properties were still very imperfectly understood (this being specially the case with gun-cotton). The liquid nature and some other peculiar properties of nitroglycerine delayed any important attempts at its application for many years; on the other hand, gun-cotton presented to the superficial experimenter so many alluring advantages as an explosive agent that its discovery was very soon followed by its manufacture and storage upon a large scale, which speedily resulted in such serious disasters that the material acquired, within a very brief period of its discovery, an unmerited, but for a long time completely damnatory, reputation for utter untrustworthiness. The stability of properly purified gun-cotton, as well as that of nitroglycerine, has, however, now been for some time past fully established, and no difficulty exists in carrying on with safety their manufacture on such a scale as to satisfy the continually increasing demand for efficient preparations of these violent explosive agents. At the same time, the experience of the last few years has afforded repeated illustrations of the terrible risks and responsibilities incurred by manufacturers of these substances by the slightest departure from conditions essential to perfection and safety of manufacture, or by a relaxation of the strictest supervision in the production, purification, and storage of the materials. The calamitous explosion at Stowmarket in 1871, and many serious explosions at nitroglycerine (or dynamite) factories during the last few years, in different parts of the Continent, have demonstrated the liability of these substances to so-called spontaneous explosion, if the acids employed in their production are allowed to remain in contact with them for protracted periods, even in very small quantities. Any negligence whatever, therefore, in the production and purification of these substances, or the introduction, by accident or otherwise, of acid impurity into the finished materials, must in all probability prove destructive of their stability, and may lead to most serious disasters.

In these respects the utilisation of explosive compounds of this class involves special risks not attendant upon the manufacture of gunpowder and modifications of that substance; in others, however, it presents important elements of comparative safety. Thus, with proper precautions, the conversion of glycerine into nitroglycerine may be carried on with safety; the purification of the substance is not attended by any danger, and the manipulations attendant upon its conversion

into suitable preparations for use (*e.g.* dynamite) are also in themselves perfectly safe operations. Again, the manufacture and purification of gun-cotton, and its conversion into the compressed or granulated substance, are absolutely safe operations, the material being wet throughout the entire course, and therefore quite uninflammable, until, when completed, it is dried by long exposure to air, or by artificial heat. On the other hand, gunpowder, and all preparations of similar nature, are explosive from the very commencement of their manufacture; the roughly mixed ingredients already furnish a material which deflagrates violently when a spark reaches it, and the subsequent operations of intimate mixture or incorporation, compression, granulation, &c.—which are necessarily carried out with the nearly dry material—are all of a highly dangerous character, demanding for their safe performance the strictest attention to precautions which have been dictated by practical experience and knowledge of the sources of danger to be guarded against.

Accidents at gunpowder factories are very frequent, and though they may not often involve considerable loss of life or destruction of property, the fact that their occurrence must in most instances be caused by partial, occasional, or complete and persistent neglect of precautions absolutely essential to the safety of the people employed in the works, or to a reduction of the risks of accident to the minimum, points to the necessity for improved legislation connected with manufactories of gunpowder and other explosive preparations, whereby the proper attention to regulations and precautions for safety may be rendered compulsory, and seconded by an efficient system of inspection. The absolute exclusion of lucifer matches from such works; the adoption of every possible precaution for excluding grit from all buildings in which the explosive substance is submitted to any kind of operation, by proper construction and closing of the buildings; the employment of special shoes and other external clothing for use in the buildings only; the total exclusion of iron, in any form, from the works; the proper separation from each other of the buildings in which the several operations are carried on, and their construction with a view to divert the force of a possible explosion into comparatively harmless directions; the reduction within particular limits of the quantity of explosive allowed to remain in any one building; the provision of efficient lightning conductors—such are some of the principal precautionary measures which go far to reduce the possibility of accident in works of this kind (or the mischief accruing from such accidents when they do arise), and the adoption of which does not present any serious difficulty. And lastly, though properly first in importance, the manufacturers of gunpowder and other explosive agents should not only themselves possess some scientific as well as practical knowledge of the nature and properties of the substances in the manufacture of which the lives of their workmen are at stake, but they also should ascertain and insist that at any rate the persons who act as managers and foremen in their factories should not be deficient in the elementary knowledge indispensable to a proper performance of their duties.

Major Majendie, the Government Inspector of Gunpowder Works,

&c., has reported officially that he was "much struck, in the course of his inspections, with the extraordinary ignorance of even the most elementary dangers, and the precautions necessary for avoiding them, which prevails among persons in charge of important factories and magazines;" and that there can be no doubt that to the ignorance and incompetence of such persons a large number of the accidents which occur are indirectly due. Surely it is in the interest of employers to adopt measures for securing that the management of their works is in the hands of competent men, experienced in the details of the manufacture, and possessing adequate general education and technical knowledge to fit them for posts of such responsibility. The obvious mode of securing this is to render it compulsory for such men to obtain certificates of competency before they can hold responsible appointments in manufactories of gunpowder and other explosive agents.

The manufacture of fireworks, ammunition, percussion caps, and other articles involving the application of explosive agents, is, it need scarcely be stated, attended by liability to accidents similar to, and sometimes even greater than, that existing in manufactories of gunpowder and materials of similar nature, and necessitates the adoption of precautions of the same nature as apply to these works.

Such necessity has, however, been very much disregarded in the arrangement and management of factories of this kind; and many very sad casualties have resulted either from utterly inadequate arrangements for localising explosions and reducing them to small proportions, by regulating the quantities of material dealt with in one building, and sufficiently separating and subdividing the manufacturing operations, or from neglect of simple regulations for excluding sources of fire from the buildings. Thus, in enquiries following on explosions at ammunition or firework factories, it has been found in some instances a common practice for the men to wear their ordinary clothing when in the factory, and to carry lucifer matches about them. Again, at an ammunition factory at Birmingham, where an explosion not long since resulted in the deaths of fifty-three women, it was brought to light during the inquest that there were open stoves, not even provided with fenders, in the middle of the sheds in which the powder-work was carried on. At these stoves the women used to cook their dinners, and they were also in the habit of shaking the grains of powder off their aprons into the stoves.

Other and special sources of danger exist sometimes in connection with this branch of the industry of explosive substances. Great stress has been laid upon the dangers which may arise in the manufacture of gun-cotton, and nitroglycerine preparations, from the liability of those substances to spontaneous change in consequence of the readiness with which their stability may be affected by imperfections in their manufacture. But there are several important instances of accidental explosions on record which have occurred in the manufacture of pyrotechnic compositions and other articles of explosive nature, in consequence of a liability to the establishment of chemical activity between the ingredients of such preparations by even very slight inciting causes. Thus, certain descriptions of coloured fires are readily susceptible of so-called spontaneous ignition or explosion, either simply from the unstable nature of one or

other of their ingredients, or from so apparently trifling a cause as the absorption of a small amount of moisture, or the employment of a small quantity of an easily oxidisable oil or fat in connection with their application to pyrotechnic purposes. Two remarkable instances of unforeseen danger in dealing with materials of this kind, even when their stability, under normal conditions, is beyond question, have come under the notice of the speaker. In one case, an explosive mixture, prepared for use in percussion caps, was preserved in a moist condition with the view of storing it in a non-explosive form, but this very precaution gave rise to a serious explosion; chemical activity became established between the components of the mixture, through the agency of the water, attended by development of heat and the speedy production of violent chemical change—a result which would certainly not have occurred had the mixture been kept dry. In the other instance, some signal lights, composed of a mixture of ingredients which long experience had shown to be in every way as permanent as those of gunpowder, were found to be undergoing decomposition to an extent which, had it not been noticed in time, must have resulted in serious consequences. The cause of this change baffled enquiry for some time, but ultimately it was clearly established that a very minute quantity of free acid contained in the paper linings of the cases in which the composition was confined (and derived from the antichlore used in the manufacture of the paper) had set up an action between the saltpetre and the orpiment composing this material, which spread gradually but with increasing rapidity through the highly compressed mass, being of course accelerated by the heat developed. Such occurrences afford instructive illustrations of the dangers which surround the manufacture and application of explosive substances, and of the necessity for combining continued study with untiring vigilance in dealing with these branches of manufacture.

Many of the most distressing accidents connected with firework manufacture have occurred in dwelling houses of the lower class, situated in crowded districts, in which not unfrequently several families reside, and where people, generally in very poor circumstances, have carried on the manufacture of squibs, crackers, or pin-wheels, which they have either retailed, or generally supplied to more extensive firework makers or sellers. This production of fireworks has almost always been carried on illegally—*i.e.*, without the maker having obtained the licence necessary, under an existing Act of Parliament, to enable him to manufacture fireworks; hence work of this kind has mostly been conducted as secretly as possible, other dwellers in the same house being often unaware of the dangerous operations carried on in the house itself, or sometimes in small sheds or outhouses. It can only be matter of surprise that firework accidents have not been more numerous, when it is remembered that the processes of mixing the firework compositions, ramming them into cases, &c., have frequently been carried on by these illegal makers in the common dwelling room, the several members of the family, old and young, taking part in the work, while cooking and even smoking may have been going on in the same room, and the work continued by candlelight in busy seasons, the powder or finished fireworks being placed in a cupboard in the room, or perhaps in places afford-

ing even less protection. This illegal firework making has been greatly checked of late by vigilance on behalf of the Government officials, and it is to be hoped that it will disappear almost entirely when new regulations are introduced which will facilitate the profitable employment of these small firework makers upon sufficiently extensive and properly organised premises of large manufactories; thus reducing the temptations which have hitherto existed for large vendors to purchase cheap fireworks of the poor people who carry on the manufacture illegally, and for the latter to convert their dwellings into sources of danger to themselves and their neighbours.

The fearful recklessness with which gunpowder and other explosive agents are handled and used by uneducated persons, such as these small firework makers, of which there are large numbers in the mining and manufacturing districts, and by the most extensive consumers of powder—namely, the miners and quarrymen—can scarcely be realised by anyone who has not had opportunity to acquire by personal observation a knowledge of the state of things. A miner may be seen with his naked lamp or tallow candle fixed in his hat or plastered against the rock close to the blast-hole he is about to load, pouring the powder into his rough measure, or his cartridge case, from the flask produced from a pocket which is often also the receptacle of lucifer matches, and at times of a half-finished pipe of tobacco (if he has not the pipe actually alight in his mouth). Having inserted the charge into the hole, he will proceed with the operation of *tamping*, which consists in ramming *débris* of the rock into the hole as tightly as possible by means of a heavy iron tool and a hammer. Grains of powder lying upon the sides of the hole, and sometimes forming a train to the charge at the bottom, are thus frequently submitted to most violent friction, and it is wonderful that accidents in this process of loading are not more frequent; but when, in spite of oft-repeated cautioning, the miner proceeds to submit to the same, and sometimes even to more violent treatment a cartridge of gun-cotton, dynamite, or other explosive agent ignited more readily than gunpowder by friction (and which is tightly confined in the blast-hole by the act of ramming with a heavy tool), it is not a matter of surprise that fatal accidents should occur during the employment of these substances by the miner, although he is exposed to less danger with them when carrying them about his person or handling them for actual use, because they are not violently explosive in small quantities when unconfined.

It is, however, more particularly from the fact that there are no regulations forbidding or restricting the making up in dwelling houses of blasting cartridges, mining fuzes, and the so-called powder-straws used in blasting, that the chief liability to accidental explosions in mining districts arises. Miners are constantly in the habit of keeping considerable quantities of powder in their dwelling rooms, and making up their cartridges or fuzes (straws) at night. In a recent official report the Head Constable of Middlesborough stated, "In one case, at Eston, the roof of a house was blown off, and on enquiries being made respecting it, the man . . . . stated that he was tallowing the end of the straw, when he put it too near the candle flame, which ignited the straw; he threw the straw away, and it fell into the barrel of powder, which exploded."

The Head Constable of Richmond, in Yorkshire, reported as follows:—"I have seen miners with a quarter cask (25 lb.) making their charges by the fire frequently, and they generally keep it under the bed or in the pantry, where their children have access to it." At Wigan, a collier was filling cartridges from a can of powder, when a spark from the candle fell into the can and produced a serious explosion. In another instance a boy was left alone in a house where an open barrel containing 7 lb. of powder, with a piece of wood simply placed over the head, was in the bedroom. A box of matches was known to be in the room, and it is supposed that the boy, who died from injuries received, exploded the powder by means of them.

Numerous illustrations such as these could be quoted of the fearfully careless manner in which powder is very generally dealt with in manufacturing districts. It naturally follows that other explosive agents, such as dynamite and gun-cotton, should be treated with similar and perhaps even greater recklessness. The apparently less dangerous nature of such materials when unconfined tends to render the miner even more regardless of precautions, and hence it is unquestionably wrong to foster the notion of the safety of these materials in the hands of the miner, especially as it frequently occurs that the men who use these materials are unable to read the printed instructions which are supplied by the manufacturers with the cartridges for the purpose of guarding against accident. Thus several frightful accidents have occurred through direct exposure to the fire of frozen cartridges of dynamite for the purpose of thawing them,* and the apparently harmless nature of dynamite and compressed gun-cotton has on more than one occasion caused the miner, when a charge has become jammed in a blast-hole, to endeavour to drive it home with his rammer, with all the force at his command—with what result need scarcely be stated.† The wholesome effect of stringent regulations which keep constantly before the minds of the ordinary operative the dangerous nature of gunpowder and all operations connected with it and with other explosives, is well exemplified by the care and caution which generally become developed as characteristics in the men employed in Government factories of this class; and although there is but little hope of the possibility of enforcing even the mildest precautionary measures with the miners themselves, it can hardly be doubted that their minds must become to some extent influenced by example, and that, by constantly witnessing the strict enforcement of precautions at the stores to which they resort to obtain their supplies, they must in

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* The necessity for thawing dynamite cartridges before use in cold weather, and the disregard of instructions furnished by the makers for doing this with safety, constitute one of the chief causes of accidents with this material. Fatal explosions have resulted from the placing of cartridges in front of a fierce fire or upon a stove. Quite recently, a pit sinker, at Mountain Ash, placed some dynamite in the oven of the fireplace in his house, and sat down to breakfast. Before the meal was ended the dynamite exploded, killing the man and injuring two others.

† A fatal accident occurred quite recently at Ebbw Vale in consequence of a man using great force in ramming a dynamite charge into a blast-hole with a wooden rammer. The printed instructions distinctly laid down that the cartridges were never to be rammed. It came out at the inquest that the partner of the man killed could not read.

time become impressed with the necessity for the exercise of some amount of care in handling explosive substances.

It does not admit of dispute, however, that the recklessness of the miner has actually been fostered hitherto by the utter disregard of all ordinary precautions which they must but too frequently witness at the stores where the powder is sold or issued to them. The practices of small dealers in gunpowder present illustrations of ignorance and recklessness, if anything even more appalling than those which the habits of the miners furnish. The manner in which powder is often dealt with by those in charge of the stores or magazines in quarries or mines, and who have to issue supplies to the men, may be illustrated by one or two examples from a Report to the Home Office by Major Majendie. At a quarry in Scotland, he was conducted by the man in charge to a magazine containing about 6 cwt. of powder. For this purpose the man lit a naked candle; as they entered the door it was blown out by the draught, but the man produced some matches from his pocket and rekindled it. When asked how he issued the powder to the men, he held the candle with his left hand, and ladled the powder out with the other hand. The practice of smashing in the head of a powder-barrel with an iron crow-bar is stated to be a very common one, or else a large stone is used, or a hole is bored into the head with a steel bit; and, as an extreme instance of recklessness, the case of a man is quoted who was in the habit of boring into the barrels with a red-hot poker. On one occasion, the lid of the barrel being thinner than usual, the heated iron was thrust into the contents of the barrel, and the man fell a victim to his very original mode of dealing with packages of gunpowder.

In some mining districts it has been customary to pay no regard whatever to the suitability, in point of safety, of the localities selected for the storage of powder. It has not unfrequently been kept in large quantities (*e.g.* 500 lb.) in ordinary buildings, quite close to dwelling houses. An instance is quoted in an official Report by a chief constable of about 3 cwt. of powder being kept in a colliery lodge constantly used by workmen, and in which a fire was regularly kept. Even where magazines have been provided, in connection with extensive mines and quarries, many instances are on record of gross ignorance or carelessness in regard to the precautions essential to the safe handling of gunpowder. The men who go to the magazines for supplies of powder, and even the man who is in charge, are allowed to enter the building in their iron-shod dirt-covered boots, often coming to the store smoking, the pipe being merely put into the waistcoat pocket when they get close to the building; the barrels containing loose powder are often left unheaded, and powder grains lie upon the floor; the door of the magazine in some instances opens inwards, scraping the floor as it is pushed open. A magazine in which this utter want of precautions was observed in the most extreme degree contained several tons of gunpowder. In illustration of the way in which explosions occur at such stores, it may be mentioned that some children saw some loose powder outside a store (in Cornwall), and set fire to it; the contents of the building were thus exploded, there being a train of

powder grains leading under the door to the stock of powder in the building.

The strenuous exertions of the Government inspectors during the last few years have already resulted in a considerable amelioration of this lamentable condition of things, although the existing state of the law affords them little power to enforce simple regulations which are vital to the safety of the people employed, and often of the neighbourhood; but scant regard being but too frequently paid to the position of even extensive stores or magazines with reference to contiguous habitations.

The fearful explosion which occurred at a gunpowder merchant's magazines at Erith, containing 51 tons of powder, in October, 1864, and the explosion at Liverpool, in the same year, of the ship "Lottie Sleigh," laden with 11½ tons of powder (through the accidental spilling and ignition of some paraffin oil), directed public attention at that time to the existing laws relating to explosives just as forcibly as did the recent explosion in London, and their very defective condition was then, as now, apparent. No steps have been taken since that time, in the way of legislation, to afford the public greater protection from dangers arising out of the storage and transport of gunpowder, or to bring the doings of powder makers and consumers more under legal control, although the Government did in 1865 contemplate for a time the enactment of new laws relating to explosives.

Very considerable alarm was felt then, as lately again, at the possibility of most calamitous disasters arising out of the collection of very large stores of gunpowder, by powder merchants as well as by the Government, in particular localities—some of them in close proximity to populous districts. In some instances, representations to the Home Office, which were followed by efficient inspection, made at the instance of Government by Colonel Boxer, led to the closing of extensive merchants' magazines existing in objectionable positions, or to a considerable reduction in the amount of powder stored in them; but it does not appear that any substantial improvement occurred in the extent to which precautions vital to the safety of the magazines were observed or attempted to be carried out by persons in charge of them.

The subdivision of the reserves of gunpowder, which it is the duty of the Government to maintain to as great an extent as is compatible with efficient arrangements of inspection and with the exigencies of the service in time of war, is unquestionably most advisable. It is admitted to be desirable that the magnitude of depôts of powder at some of the principal establishments should be reduced in extent, and in some instances extensive depôts which existed in close proximity to towns have been removed or reduced to insignificant proportions. It must be borne in mind, however, that the possibility of the explosion of magazines, where powder is simply stored as a reserve, emanates almost exclusively from causes external to the depôts themselves; and that as long as these are situated at such distances from habitations as will secure them against fire reaching any part, the precautions adopted by Government to guard against accidents from electric discharges, and against the possibility of any danger arising within the establishments

themselves, render such depôts quite safe, provided operations connected with gunpowder (such as the making up or breaking up of cartridges) are not carried on at or in close proximity to such magazines. It is only in conducting manipulations with gunpowder that danger may arise (from any causes excepting fire or electric discharges); and therefore any operations with powder, such as the making up of cartridges, or any transactions involving the frequent issue and receipt of powder, or the opening or re-packing of powder packages, should be imperatively conducted in establishments distinct from those simply devoted to the preservation of reserve supplies.

The recent powder explosion revived the discussion which arose some years ago as to the probable advantages to be derived, in point of safety, from a dilution of gunpowder, for purposes of storage and transport, with some incombustible non-conducting material, which, by isolating the grains from each other, would prevent the transmission of fire from one to those surrounding it. Although quantities of gunpowder may thus be rendered practically non-explosive, there can be no doubt that the possibilities of accident must be considerably increased by the additional manipulations to which the powder must be subjected in the application of such a safeguard. If, as in the case of compressed gun-cotton, gunpowder could be preserved in a sufficiently wet condition to be perfectly uninflammable, the drying, as a final manufacturing operation, being simply deferred until the material was required for use, the protection afforded by a diluent could be secured without the introduction of any extra operations involving, by their adoption, the usual risks invariably attendant upon manipulations with an explosive. The impracticability of such a course need, however, be hardly pointed out. In this particular respect, therefore, gun-cotton possesses a decided superiority over gunpowder, especially as for almost every purpose to which it can be advantageously applied it may be employed in the wet perfectly uninflammable condition as effectively as if perfectly dry, by the adoption of very simple modes of exploding it.* Supplies of gun-cotton in the condition in which it can actually be used without further preparation may therefore be stored without the precautionary measures indispensable in the case of gunpowder.

Experiments on a considerable scale made by the late Government Committee on Gun-cotton, &c., demonstrated conclusively that when stored in *small* quantities (two or three hundred pounds) dynamite and dry gun-cotton are unquestionably much less dangerous in their character than gunpowder. Such quantities, even if confined in strong boxes and contained in buildings filled with inflammable matter, may burn away entirely, when these are set on fire, without developing explosion; but the burning of 5 to 6 cwt. of these materials under similar conditions may terminate in an explosion, unless they be less

* In experiments recently conducted by the late Gun-cotton Committee at Eastbourne, two separate tons of compressed gun-cotton, in the wet condition in which it is now stored by Government, were exposed to fierce fires in strong magazines, the gun-cotton being confined in stout boxes and in wooden tanks. No explosion occurred; the gun-cotton was slowly converted into gases and vapour.

strongly confined; and there is no doubt that very considerably larger quantities, if set fire to, will not even need other confinement to develop an explosion than that to which the interior of the mass of explosive is subjected by the external portions, and by the pressure of gas developed by the fierce burning of the substance. The degree of comparative safety with which explosive materials of this description may be stored is therefore regulated by the quantity and the extent of confinement, and hence great caution must be exercised in relaxing in their favour the precautions and restrictions applied to gunpowder. Indeed, the prudence of relaxing them at all is questionable, as the result may be the fostering a sense of security in those who have to use these substances, which, by encouraging negligence and forgetfulness as to the properties of the materials dealt with, may be productive of disastrous results.

A regulation of the quantity of an explosive stored in one place, and of the mode of storage, by the nature of the particular material, and the circumstances which may tend to develop its violent explosion, would involve a combination of complex rules with an impractically comprehensive system of supervision; and it is therefore obviously not only wise but also necessary to deal with the storage, upon an extensive scale, of all explosive substances upon the broad general basis of their being susceptible of violent explosion from accidental causes; any relaxation in favour of the comparatively safe materials being suffered only to apply to small quantities.

The safe *transport* of gunpowder and other explosive agents demands the application not only of many of the precautionary measures which should be observed in their manufacture and storage, but also of certain others of special character, to meet the liability to casualties arising out of the ordinary accidents of locomotion, and out of the more or less unavoidable exposure of the explosive agents during transport to treatment and conditions involving risk of accident. Thus the submission of packages of gunpowder and many other explosive substances to the continued concussion unavoidable in transit by road or rail necessitates the employment of strong and thoroughly sound or tight receptacles, so as to prevent the escape of fine particles or dust from the packages into the conveyances, and the possibilities of accident resulting therefrom. Again, the transmission of both large and small quantities of explosives by land or water must be governed by well-defined rules regarding the extent to which the transport of such materials should be kept distinct from that of other goods, and the manner of ensuring this; the nature and construction of the conveyances specially devoted to, or occasionally selected for, their transport, and the conditions generally under which such transport shall be accomplished.

The utter inadequacy of the existing regulations as to the conveyance of powder, &c., by land or water, and the flagrant manner in which even these defective regulations are but too frequently disregarded, are matters to which public attention has been much directed since the explosion in October last, and which are but in harmony with the negligence and ignorance displayed to so alarming an extent in connection with the handling and storage of gunpowder. Thus, the packages

(barrels, &c.) in which powder is transmitted to distant places are often so imperfectly constructed that the grains escape into the cart, or the hold of a vessel in which the powder is stowed, where they may become mixed up with grit and be eventually trampled upon. As regards the vehicles in which the powder is transported, some regulations exist with respect to the employment of covered or uncovered carts with reference to quantities of powder exceeding considerable limits; but there is no law requiring carts or barges to be specially constructed or employed so as to exclude sources of danger (such as grit, employment of iron fastenings, &c.) In the mining districts, and even in towns, powder is constantly conveyed in dangerous quantities in ordinary carts, which may have been used for carrying stones, coal, or road rubbish. It may be and frequently is conveyed in carts with other goods, such even as lucifer matches and petroleum; there is no regulation to prevent the person in charge from smoking while in his cart, or stopping at a public house, leaving the powder standing at the door, and Major Majendie reports that such occurrences are frequent.

Public conveyances often carry packages of powder without any precautions, other than perhaps a caution to a passenger who may unwittingly be exposing himself and companions to immediate danger. Thus there is a case officially recorded of a man who, on getting on to an omnibus at Wigan, was requested to put out his pipe, as the passenger next to him had 100 lb. of powder in a barrel beside him. The conveyance of large quantities of gunpowder in a number of wagons passing close together through towns has been no uncommon occurrence; thus Major Majendie discovered that it was a practice in Edinburgh to convey as much as twenty tons and upwards of powder at one time through the streets, the public having thereby incurred the greatest possible risks, through smoking going on while the carts have been standing in crowded places. A similarly extensive conveyance of powder through the most populous districts of London for transfer to ships at wharves has often taken place; and it may be quoted, as one of many instances mentioned by the police authorities, that a train of fifteen vehicles loaded with about twenty tons of gunpowder passed from Camden Town to Blackwall Stairs (a densely populated place) to be shipped off, the whole of the loaded vans being detained in the street for some time for the arrival of the barge to which the consignment was to be transferred. Railway companies, as a rule, adopt comparatively efficient precautions with respect to the transport of powder and explosives. The former is conveyed, when in sufficient quantities, in vans specially constructed, and more or less well adapted to the purpose, or, when the quantities are comparatively small, in barrels separately packed in specially constructed metal cylinders. With regard to the conveyance of other explosives and of small packages of fireworks, the regulations and charges adopted are in most instances so restrictive that they lead to much surreptitious carriage of such goods, whereby passenger- and goods-trains are often exposed to great risk.

The carriage of powder and other explosives by water should be the safest mode of conveyance, if proper regulations could be enforced; but here again the Regent's Park catastrophe has afforded a terrible example

of the danger to which the public has been continually exposed by the profound oblivion which appears to have reigned in the minds of those engaged in the transport of powder by water-traffic as to the explosive nature of this material. The arrangements made by Government for the transfer of gunpowder by barges from the factory to the depôts, illustrate the nature of the precautions which are regarded as indispensably necessary by those who have well considered the subject. No iron whatever is allowed to enter into the construction of the barges; the men engaged in stowing the powder wear special shoes and clothing; every particle of grit or dust is most scrupulously removed before the powder packages are introduced, and these are very carefully and securely covered in. The bargemen are strictly prohibited from smoking and carrying lucifer matches either about them or in any part of the vessel; no fire is permitted on board during the loading, carriage, and unloading of the powder, and the strictest regulations exist with regard to the manner in which the journeys are to be performed. The barges are, moreover, provided with valve-arrangements by means of which they may be sunk in a very short space of time, should danger of fire arise from neighbouring barges or other sources.

In other vessels used occasionally for the transport of powder by Government the foregoing precautions are carried out as far as possible; the vessels are not specially constructed, but, in order to exclude all iron fastenings and accidental grit from contact with the powder barrels, hides and thick woollen covers are spread over the bottom and sides of the vessel. Although the barges of canal owners and others are subjected to this practice when carrying powder for Government, it has not been so with regard to the freights of powder carried for merchants; and regulations respecting abstinence from smoking, or exclusion of fires or matches, have been avowedly of the most lax description, or have even become a dead letter, although the existing law is thus set at defiance. The practice of carrying lucifer matches about the person, and of smoking, has unquestionably been among the most prolific sources of accidents connected with gunpowder, and it need scarcely be stated that they are almost the most important dangers to be guarded against in the transport of powder in barges. During the inquest which followed the great explosion at Erith in 1864, it transpired that lucifer matches were allowed, as a rule, on board the barges and vessels carrying merchants' gunpowder; and while one powder barge was unloading, another empty one by its side was seen to have a fire on board. The falling of a match from a man's pocket while he was engaged, in a stooping attitude, in moving the powder packages from the barge to the magazine was considered by Colonel Boxer, after careful investigation, to have been the most probable cause of that explosion.

Another source of danger, which, viewed in conjunction with the non-exclusion of sources of fire, is of a most alarming nature (and which has evidently been of common occurrence), is the carriage of gunpowder in barges as part of a miscellaneous cargo. There are obviously many goods which may be transported together with powder without danger to the latter, although the special care which gunpowder should always receive renders its isolation from other goods desirable under all

circumstances. Recent experience has, however, demonstrated that it has not been the custom to exercise any discrimination in the stowage of packages of gunpowder with other goods, when the former was insufficient in quantity to constitute a barge load. It is scarcely to be realised that the indifference with which gunpowder has been treated by those who undertake its transport by water could have attained such an extreme that powder packages could be stored in the hold of a barge side by side with casks of petroleum spirit, by persons whose experience must have made them cognizant of the liability to leakage of petroleum from such casks. Such leakage (occasioned perhaps by rough handling in placing it on board) must inevitably furnish in course of time an explosive atmosphere by the diffusion of inflammable vapour through the air confined in the barge-hold (which is closely covered in); the extension of this explosive mixture to the small opening which these barges contain in the bulkhead separating the hold from the small cabin, or its penetration through crevices in the bulkhead, is but an affair of time; and then, whichever of the several sources of fire provided on board the barge—*i.e.*, the stove, lamp, or lucifer matches—happens to come within reach of the quickmatch which the explosive atmosphere constitutes, completes the arrangement for inflaming any small quantity of petroleum which may have leaked out on, or in close proximity to, a powder barrel. But for the fact that a concurrence of several conditions is essential to the communication of fire to gunpowder, through the agency of a leakage from a petroleum cask in a confined space, it can scarcely be doubted that the rude awakening which the public recently received to the danger they were frequently exposed to in the vicinity of canals where powder traffic goes on must have occurred long since. The simple flash produced by the ignition of a mixture of hydrocarbon vapour and air would probably not suffice to ignite powder-grains exposed to it; but any small quantity of the liquid itself which, leaking from a cask, has furnished the vapour, may be in close proximity to a few grains of loose powder, or upon a powder barrel which is not securely closed, or some other simple conditions resulting in the conveyance of the fire to the powder may be fulfilled, and then explosion must ensue.

The imperative necessity for better legislation in reference to the transport of powder has been so convincingly demonstrated by the Regent's Park disaster, that the long-contemplated revision of the law relating to explosive agents would, there is little doubt, have been hastened thereby had the serious attention of the Government not already been devoted to this subject. During the first two years which succeeded the appointment of Government Inspectors of Gunpowder Factories and Magazines, the unceasing labours of Major Majendie resulted in so convincing a demonstration of the utter inadequacy of the existing laws relating to the manufacture, storage, transport, and use of gunpowder and other explosive agents to afford protection to the public and to those dealing with these substances, that the intention (already entertained by the Government in 1865) of framing a bill to amend the Gunpowder Act was actively pursued by the late Ministry in 1873. Although the submission to Parliament of new measures was

delayed by the change of Government, this delay has been productive of benefit, inasmuch as the present Government has secured most important aid in the preparation of the comprehensive bill which has recently been submitted to Parliament, from the labours of a Select Committee, appointed last session to enquire into the working of the existing laws and the directions which fresh legislation should take.

The rapid development which has taken place in the manufacture and use of other valuable explosive agents has considerably increased the necessity for comprehensive measures regulating these important branches of industry. When the introduction of nitroglycerine into this country, a few years ago, was speedily followed by numerous deplorable disasters, the protection of the public demanded the imposition for a time of severe restrictions in dealing with an explosive agent of most violent character, the nature of which was still very imperfectly understood. A measure was therefore made law in 1869, whereby the employment of nitroglycerine itself and of its preparations was placed entirely under the control of the Government. Although this arrangement involved great labour on the part of the Government officials, and placed what now certainly appear to be unduly severe restrictions upon the manufacture and employment of dynamite, its necessity and beneficial operation as a temporary measure have been fully admitted by those chiefly interested in the progress of nitroglycerine preparations; and there is no question that it importantly promoted the *wholesome* development of the application of dynamite in Great Britain, where it has during the last three years secured a firm footing as a material indispensable to mining industry. The existing laws relating to nitroglycerine preparations can now be modified with great advantage, and no important difficulty should be experienced in including in a general Act the measures necessary for developing and regulating, with proper security to the public, the production of this and other valuable substitutes for gunpowder, in such a manner as not to hamper the powder industry with undue restrictions. Other long-established branches of manufacture connected with explosive materials, which are quite as dangerous as many of new creation, but have enjoyed comparative immunity from restrictions, will also be brought under the operation of that systematic supervision which the security of the public demands.

It is obvious that to attempt to deal in detail in one, or more than one Act of Parliament with the various modifications of regulations specially applying to gunpowder, which the peculiarities of other explosive agents, or of branches of manufacture involving risk of explosions, necessitate, would be to overburden the law with an unwieldy mass of measures which, however circumstantial in their nature, would certainly fail to embrace all conditions and contingencies likely to arise. Hence the wisdom (which has been so clearly demonstrated by the Nitroglycerine Act) of entrusting the Government with discretionary powers, under the operation of a comparatively simple but sufficiently comprehensive Act of Parliament, can scarcely admit of question.

The beneficial results attainable by a systematic and thoroughly authoritative supervision, by Government inspectors, of factories and stores of explosive agents, if conducted with intelligence and discretion,

have been most convincingly demonstrated by the great good which it is admitted on all sides that the inspectors have already succeeded in accomplishing, even with the very insufficient powers which the present state of the law affords them. The favourite argument of some, that Government inspection must operate mischievously, by diminishing private responsibility, has certainly received no support from the results of inspection, so far as the experiment has been tried. It will scarcely be asserted that a manufacturer or store-holder who may have willingly adopted, as suggestions which the inspector has no power to enforce, measures conducive to the safety of life and property, would be careless in the application of those measures because their adoption was no longer optional, or because the responsibility for their due observance was to some extent shared by the inspector. This very system of inspection cannot fail to benefit those interested in different branches of the industry of explosives, by reducing the necessity for hard and fast rules with respect to the arrangement and conduct of works, which might in many instances entail hardship or inconvenience without any real necessity, and by strengthening the hands of factory owners, and thus rendering comparatively easy the proper observance and enforcement of regulations for the safety of the men and the works. It is, however, especially in connection with the storage, transport, and employment of gunpowder and other explosives in mining districts that efficient inspection, supported by the reasonable power which a well considered Act of Parliament cannot fail to afford, may be confidently expected to produce important beneficial results, not the least of which will probably be the wholesome influence exercised indirectly by the force of example upon the miner or pitman, whose ignorance has fostered the indifference with which long habit has led him to regard the possibility of danger.

But although improved legislation, and the beneficial regulations thus supplied, may be confidently hoped to effect an important reduction in the number and magnitude of the disasters now recorded as accidental explosions, it would obviously be worse than shortsighted to encourage a reliance upon legislation alone as a safeguard against the evils which lead to casualties of this kind. Punishments inflicted for transgression of the law may engender caution, but the disasters which arise from ignorance are not likely to be importantly reduced in number by legislative enactments alone.

It is to the general promotion of education among the people, and to the spread of scientific and technical knowledge, if even of the most elementary kind, among employers and employed, that we must look for a substantial diminution of these casualties, which the uneducated mind is but too prone to attribute to accident, and the prevention of which rests, at any rate to a large extent, with those who are at present tacitly content to regard them as inevitable.

ENGLISH VERSUS GERMAN FIELD GUNS;

A COMPARISON.

BY

LIEUT. S. C. PRATT, R.A.

Till very recently it has been difficult to obtain reliable *data* as to the new German field guns. It is, however, impracticable to preserve an impenetrable veil over such a subject, and the details embodied in the following table (corrected, as far as possible, up to date) may be assumed to be nearly correct. At first sight it seems strange that the German Confederation should have re-armed the whole of their artillery force with weapons differing in no essential principle from the B.L. field guns employed in the last war. A consideration of the following figures will, however, tend to dispel any doubt as to the wisdom of the change, if it is remembered that the old 8c and 9c guns were inferior in almost every point to the 9-pr. and 16-pr. M.L. guns in our service.

	English.		German.	English.	German.
	Horse artillery 9-pr. M.L.	Light field battery 9-pr. M.L.	Horse artillery 7·85c B.L. (officially 8c.)	Field battery 16-pr. M.L.	Field battery 8·8c B.L. (officially 9c.)
Weight of gun	6 cwt.	8 cwt.	7·68 cwt.	12 cwt.	8·86 cwt.
Calibre	3 ins.	3 ins.	3·09 ins.	3·6 ins.	3·46 ins.
Preponderance	10 lbs.	7 lbs.	99 lbs.	10 lbs.	99 lbs.
Number of grooves	3	3	24	3	24
Length of rifling	62·3 ins.	59·8 ins.	60·2 ins.	58·04 ins.	58·8 ins.
Twist in calibres	1 in 30	1 in 30	1 in 50	1 in 30	1 in 50
Weight of gun-carriage packed	2057 lbs.	2320 lbs.	1966 lbs.	2957 lbs.	2163 lbs.
Charge	1·75 lb.	1·75 lb.	2·75 lbs.	3 lbs.	3·3 lbs.
Initial velocity (feet per second)	1391 ft.	1381 ft.	1522 ft.	1352 ft.	1460 ft.
Common shell (full)	9·1 lbs.	9·1 lbs.	11·2 lbs.	16·2 lbs.	15·4 lbs.
Bursting charge	7·5 ozs.	7·5 ozs.	6·5 ozs.	18 ozs.	9½ ozs.
Shrapnel (full)	9·8 lbs.	9·8 lbs.	12·2 lbs.	16·4 lbs.	17·9 lbs.
Number of bullets in shrapnel	63	63	122	119	209
Rounds carried (gun and limber)	40	40	40	28	34
Total rounds (gun and wagon)	148	148	154*	100	136*
Weight behind gun-team	3778 lbs.	4051 lbs.	3936 lbs.	4768 lbs.	4222 lbs.

* Eight ammunition wagons to each battery.

Note.—The German guns are of cast-steel, strengthened at the breech by a wrought-iron jacket. The grooves are V-shaped and diminish in size towards the muzzle. The breech is closed by a soft metal gas-check tightened up by a cylindro-prismatic wedge.

It is worthy of notice that the Germans have only two calibres—the lighter gun being used for horse artillery, and the heavier *exclusively* for field batteries. This alteration is more important than it at first seems. It is the first step to the fulfilment of the future tactical requirements of artillery, and is the recognition of the almost self-evident proposition that unequally weighted gun-teams cannot manœuvre satisfactorily together.

By a glance at the table it will be seen that the German field gun is more than 3 cwt. lighter than our 16-pr. Taking the weight complete of the gun-carriage, there is a further total advantage of 7 cwt. The weight behind the gun-team, again, of the 9^{c} gun is nearly 5 cwt. less than that of our own gun. Notwithstanding its advantage in weight, the German gun consumes a heavier charge of powder, fires a more powerful shrapnel, and has a superiority of 100 ft. a second in initial velocity.

Against obstacles the 16-pr. common shell would, on account of its large bursting charge, probably be the more efficacious; but against troops it could not compete in destructive power with the regularly dispersed pyramidal segments of the new Prussian shell. The question of weight behind a gun-team is a serious one, and by no evasion—such as employing extra horses—can we escape the dilemma of possessing a field gun heavier in draught than that of any other European power. The recoil of these guns is of course very great, and the large preponderance must exert a severe extra strain on the carriage; the fact, however, still remains that gun-carriages of a lighter pattern than our own can be made to resist it. The large number of bullets contained in the German shrapnel, as compared with our own, should be noticed. The increase in initial velocity of the new gun has necessitated a modification in the original percussion fuzes.

The new fuzes are constructed with a safety pin and are carried in the shells. According to recent experiments the alterations made have been a success—400 rounds having been fired without a premature explosion or a defective fuze being met with. A new time fuze for shrapnel has been adopted with which very effective practice at 2700 yds. has been obtained. It is not probable that opportunity will be given for some time of comparing the relative accuracy of the German and British guns. The tables hitherto published are not very reliable. There is no reason, however, to suppose that the accuracy of the 9^{c} gun is inferior to that of our 16-pr., and according to all theory it ought to be considerably greater.

The German horse artillery gun compares favourably with our 9-pr. The gun-carriage packed is lighter than that of our horse artillery gun, and the total weight behind the gun-team is rather less than in our 9-pr. field batteries. The Prussian gun consumes 1 lb. more powder, fires a shrapnel 2½ lbs. heavier, and has a superiority in initial velocity of 130 ft. a second. The 9-pr. shrapnel contains about half the number of bullets enclosed in the 8^{c} shell. It will be noticed that the German limbers are considerably heavier than our own, owing to their having one large ammunition box in lieu of our two moveable ones. But little advantage is apparent in this method of construction, and it seems

inferior to the existing arrangement in our own batteries. It is, however, employed in the new *matériel* now in process of issue.

The question of rifling is, of course, dependent to a great extent on the method of loading, charge, &c.; but the sharper twist used in the Woolwich gun should be noticed, especially as with the polygroove rifling a longer and heavier shell is fired.

It is difficult to understand the smaller bursting charges of the Prussian shell, except upon the supposition that firing against hostile troops over the heads of a co-operating infantry force is the main object sought. The peculiar construction of the shell (noticed in "Translations" issued with No. 1, Vol. IX.) favours the probability of this idea.

The breech-loading apparatus of the new guns differs but slightly from that of the former ones, the main alteration being an improved gas-check—the invention of Lieut. Piorkowski.

The English R.H.A. gun appears to be lighter in draught and to carry more rounds into the field than its German compeer.

In comparing the relative value of the artillery of the two nations it must be borne in mind that the Prussian field gun is the equivalent of our 16-pr., and that both our 9-prs. must be classed in the same category with their horse artillery gun.

R.M.C.,
May 30, 1875.

TIME FUZE,

PROPOSED BY

LIEUT. W. MARTIN, R.A.

In submitting a new fuze in addition to the already numerous patterns now in the service, I have the following objects in view:—

(*a*) The use of but one pattern of fuze, which will burn 15 seconds, and as a time fuze answer the purposes of the present 5-second and 9-second time fuzes.
(*b*) Increased accuracy of shrapnel shell fire, owing to the greater nicety with which the proposed fuze can be set.
(*c*) Increased simplicity of construction, and facility of manufacture.
(*d*) Greater strength, and non-liability to premature explosion from the splitting of the powder channels.
(*e*) Increased facility for testing its rate of burning and accuracy.

Construction.

The fuze consists of two parts—the cone, or body, and the spindle. Construction.

The cone, or body, is externally of exactly the same dimensions as the present time fuzes for M.L.R. ordnance. The cone.

It may be constructed of beech wood, or as I should recommend in India (where great difficulty exists in obtaining kinds of wood suitable for the manufacture of time fuzes) by the compression in dies by hydraulic power of fibrous substances—such as crushings of sugar-cane, cocoa-nut fibre, old rope, &c., &c. Material.

The interior consists of three concentric hollow cylinders, of different dimensions and lengths. Interior of body.

Their names and dimensions are as follows:—

The upper or spindle-head recess— Spindle-head recess.

	in.
Length	·25
Diameter	·8

The interior quick-match groove— Interior quick-match groove.

	in.
Length	·25
Diameter	·7

(The object of this groove is to receive the quick-match and priming).

Hollow for fuze composition.

The third or lower hollow cylinder—

	in.
Length	3·25
Diameter	·6

(This cylinder is constructed with the object of containing a ring of fuze composition 3 ins. in length, and which would consequently burn 15 seconds).

The Spindle.

The spindle.

The spindle consists of a solid rolled and compressed paper head, with a body of the same material, and made in one piece.

The dimensions of the head are as follows:—

	in.
Diameter	·8
Depth	·25

so that it fits accurately into, and the top of it is flush with, the top of the body.

This head rests on the shoulders formed by the difference in diameter of the spindle-head recess and the interior quick-match groove.

Body of spindle.

The body of the spindle is cylindrical—

	in.
Length	3·45
Diameter	·4

and has a powder channel ·125 in. in diameter running down its centre.

Tamping.

The lower ends of both spindle and body are undercut for a length of ·25 in. to receive the tamping, which may be formed either of a mixture of chalk and alum or of pure clay.

Composition and Priming.

Fuze composition.

The composition is contained in the ring formed by the difference of diameter of the fuze composition hollow and that of the body of the spindle. The breadth of the composition is consequently ·1 in., and is composed of ordinary fuze composition.

Driving.

The manner of driving the composition is as follows:—

The fire-holes—which are three in number, and which I previously omitted to mention—have a diameter of ·25 in.

The axes of these fire-holes are at right angles to that of the fuze, and the holes communicate directly with the interior quick-match groove.

Three stout strands of quick-match are placed in this groove, and the six ends brought out through the fire-holes (two ends through each hole).

The spindle is then inserted from the top, and passing through the triangular space formed by these three strands, secures the quick-match in its place.

The ends of the strands are then roughly wrapped round the head of the fuze, and lie in the exterior groove.

The fuze is then placed in a die, head downwards, and compressed rings of fuze composition are forced over the spindle by hydraulic pressure, until the composition hollow is filled to within ·25 in. of the end of the fuze, where the undercut on both the body and spindle has been made. This undercut groove is then tamped, as before mentioned. During the preceding operation a steel former or drift remains in the powder channel of the spindle, and is now withdrawn. The fuze is then removed from the die, and mealed powder is shaken in through the fire-holes until they are full, when the strands of the quick-match are again re-wrapped round the head, and covered in by a band, as in the present service time fuze. Priming.

Graduation and Marking.

A spiral line of ·4 in. pitch is then marked on the exterior surface of the fuze, commencing at the lower edge of the exterior groove. The exterior surface of the groove is also divided longitudinally into eight parts, by eight straight lines passing down the whole length of the fuze. The intersections which these lines make with the spiral thus mark off that spiral into spaces, each of which gives a difference of ·05 in., and as each inch burns 5 seconds, each division will mark ·25 second. Graduation.

I have adopted this plan of marking the fuze into seconds and quarter seconds, as a knowledge of the time of flight for each range will be all that is required for boring the fuze.

These divisions may be further subdivided by eye, where very great accuracy is required, as there is considerable space between each intersection.

Advantages.

With reference to the advantages offered by this construction, a glance at the accompanying sketches will readily convince anyone that the objects mentioned under heads (*a*), (*b*), (*c*), and (*d*) are attained. This is not at first sight so evident with reference to (*e*)—viz., increased facility for testing the accuracy of the rate of burning. It is, however, to be attained in the following manner :—

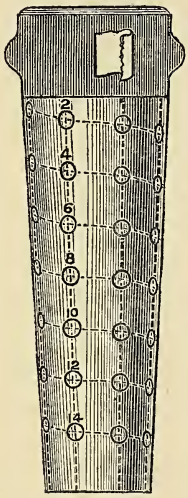
The brass disc at the bottom of the powder channel is removed, and the powder shaken out. The powder channel is then continued right through the fuze by prolonging it through the head. The lower end of the powder channel is then tamped with ·25 in. of clay. A few grains of R.F.G. are inserted from the top, so as to fill up about ·5 in. of the channel, when a small plug of clay about ·1 in. thick is placed over it, and similar charges thus introduced at every half-inch of the powder channel until it is filled. If now holes be bored through the fuze to the powder channel—care being taken that no two holes are bored into the same charge—and the fuze be ignited, the times corresponding to the boring can be accurately noted, from each separate charge (as the composition burns down to the place where it is bored) giving a distinct report.

Borer.

Borer. In all my experiments with this fuze I invariably used the old-fashioned hook borer, and never found it fail to bore accurately to the centre of the powder channel.

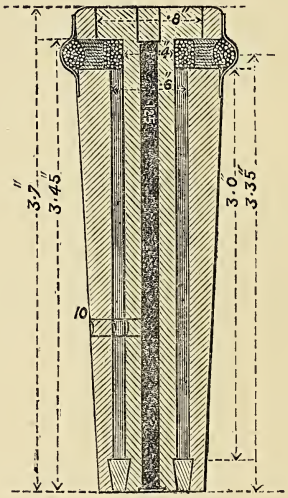
Elevation.

($\frac{2}{3}$ full size.)



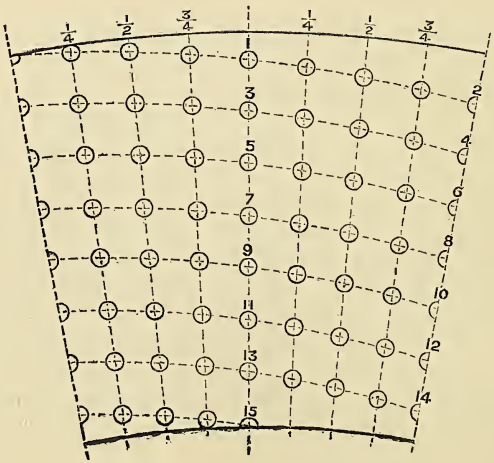
Section.

($\frac{2}{3}$ full size.)



Elevation of Time Holes.

($\frac{2}{3}$ full size, into $\frac{1}{4}$ seconds.)



OUR SERVICE SMALL-ARMS;

THEIR MANUFACTURE AND REPAIR.

BY

MAJOR F. S. STONEY, R.A.

UNDER the head of "small-arms," are included all hand weapons —whether firearms or otherwise—viz., muskets, rifles, carbines, pistols, swords, bayonets, lances, &c.; but the following pages refer principally to rifles, as the most important of all.

Firearms, following naturally on the introduction of gunpowder, crept into the English service in the 16th century, and in Queen Elizabeth's reign matchlocks superseded bows and arrows as military weapons. Towards the close of the next century, flintlocks* were introduced as an improvement on the matchlocks, and became, to the exclusion of pikes, the common infantry arm, and remained unchanged for more than a century and a half; in fact, the firearm of the British soldier at Waterloo (1815) was precisely the same class of weapon as at the Boyne (1688),† with the exception of an iron ramrod in place of a wooden one, and that the bayonet was attached by a socket over the muzzle instead of being screwed into it.

Meantime, however, in 1800, the 95th Regt. (now the Rifle Brigade) was armed with a Baker's rifle, which in 1836 was superseded by the Brunswick rifle—a weapon which had two grooves, and fired a spherical bullet with a belt which fitted into the grooves, and was furnished with a percussion cap arrangement.

In 1842 flintlocks were abolished altogether, and "Brown Bess," (smooth-bore) became the arm for our infantry.

In 1851 the Minié rifle was adopted for general use, but it gave place during the Crimean war to the Enfield rifle, which was an improvement on the Minié—the bore being only ·577 in. instead of ·702 in., and the bullet having a baked clay plug at the base instead of the iron cup,

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* The flintlock was at first called the Snaphaunce, as it was supposed to have been invented by Dutch Snaphans, or poultry stealers, who had found the lighted match a rather tell-tale contrivance at night.

† See some excellent specimens of the flintlocks of William III.'s time in the Museum of Artillery at Woolwich.

which was found not to answer its intended purpose of forcing the lead to take the grooves.

The Enfield rifle—so called from the Royal Small-Arm Factory, Enfield Lock, Middlesex—included several patterns to suit the various branches of the service; viz., the long Enfield for the rank and file of the infantry, the short Enfield for serjeants and rifle regiments, the naval rifle, the artillery carbine, and the cavalry carbine. The Royal Engineers' weapon was not, properly speaking, an "Enfield rifle," as it had a different system of rifling—namely, Lancaster's oval bore, in lieu of grooves.

Owing to the great advantages of a breech-loader for infantry, as illustrated by the needle gun in the Dano-German war of 1864, all the above, including the Lancaster, were converted to breech-loaders on the Snider plan.

Sharpe's, Terry's, and Westley-Richards' cavalry breech-loading carbines had been previously adopted on trial. Their success was only partial, for none of them had gas-tight cartridges (which is now considered essential to a breech-loading small-arm), and all were fitted for percussion caps—a most inconvenient arrangement on horseback. Terry's carbine was issued to the Cape Mounted Rifles (since disbanded), and is not now in use, and Sharpe's was used by some of our cavalry regiments in India; Westley-Richards'—which was the best of the three—is now in the hands of the yeomanry cavalry.

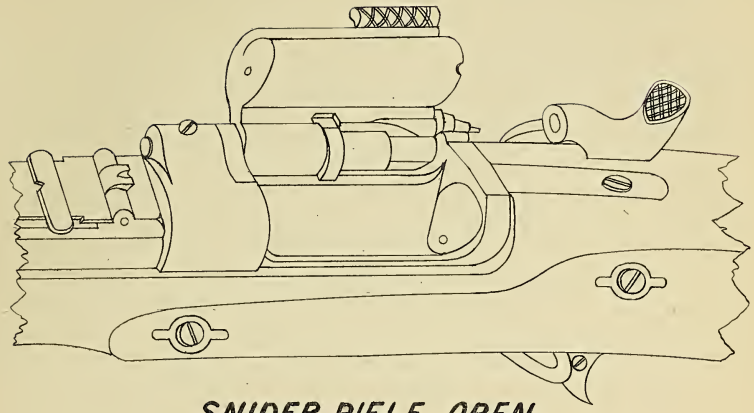
The converted Sniders were very efficient, being not liable to go out of repair,* and being three times as rapid in fire as the muzzle-loading Enfield; and—what is a very great convenience in regard to stores—all six arms (including the Lancaster) took precisely the same ammunition; but nevertheless it soon became a recognised necessity that we should obtain the very best procurable weapon for our infantry.

Accordingly, in 1866, the War Office appointed a Committee for the purpose, and offered prizes—£1000 for the best rifled barrel, and £600 for the most efficient breech-loading arrangement. Out of 104 arms submitted, the Committee selected nine for further trial. None of the rifled barrels reached the required standard of excellence, but Mr. Henry's breech-loading arrangement won for him the prize of £600.

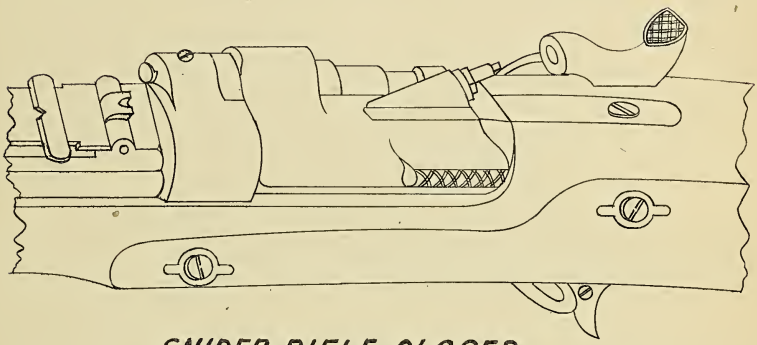
Evidence was then taken from General Hay (Hythe), Colonels Boxer and Dickson, Messrs. Whitworth, Lancaster, Rigby, Abel, Burton, Kerr, Henry, &c., &c., as to the proper calibre, length, and spiral for an infantry rifle-barrel, and it was gathered from their evidence that a barrel 35 ins. long and ·45 in. calibre would give the most favourable results. Further competition with barrels answering these conditions was accordingly invited, and took place; and at length, in 1869, having thoroughly tested the weapon for initial velocity, low trajectory, accuracy, rapidity of fire, simplicity of action, and non-liability to get out of order,† the

* One Snider rifle fired 72,000 rounds, under Major Majendie's supervision, without requiring any repair, and was still perfectly serviceable.

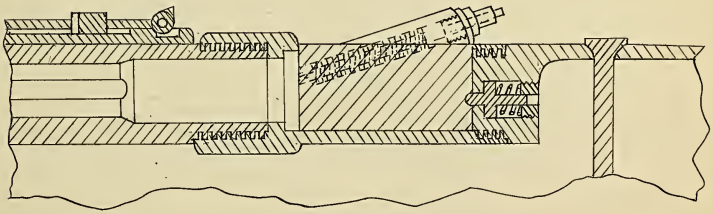
† It penetrated 14 elm planks ½-in. thick against 8 with the Snider and other competitive arms. It could be fired without aim 25 rounds in a minute. The breech-action had only 27 parts, whereas the Snider had 39, and it stood the test of sand, water, and rust to which it was exposed. It has, however, been asserted very recently that premature explosion is likely to take place from the accumulation of sand or rust under the trigger-shoulder.



SNIDER RIFLE, OPEN.



SNIDER RIFLE, CLOSED.



SECTION THROUGH SNIDER BREECH ACTION.

Committee awarded the palm of victory to the Martini-Henry—that is, a rifle with the Martini breech-action* and the Henry barrel—and recommended it to Government as the most suitable weapon known for infantry.

Before, however, the authorities decided on adopting the Martini-Henry, the weapon was practically tried by some of our troops in different parts of the world, and having withstood all the tests of climate and the rough usage of the rank and file, it was at last adopted (in 1874) for the British army and navy.†

All the regiments of the line are now armed with the Martini-Henry in place of the Snider, hitherto in use, and which still remains the weapon for our militia, volunteers, and some of our native infantry Indian regiments. The Martini-Henry is the weapon also for the Royal Navy and Royal Engineers, to the exclusion of the naval and Lancaster rifles; and it will probably be adopted, in a smaller size, by the artillery and cavalry. There are no smooth-bores in either the regular or auxiliary forces, with the exception of those issued to some of the native troops in India, and a few 6-in. pistols in the hands of the Coast Guard.

Lancers and troop serjeant-majors of cavalry are still supplied with the old rifled 10-in. pistol, but revolvers are issued to the Navy Coast Guard and Police.

Table I. gives the dimensions of the various central-fire breech-loading rifles in the service at present.

A full description of the service small-arm cartridges will be found in the Royal Laboratory "Treatise on Ammunition, 1874." It will be sufficient to describe here the latest pattern (Mark III.) *Martini-Henry cartridge:—*

With the exception of being bottle-shaped, it is in general construction similar to the cartridge for the Snider arm, having a brass gas-tight case; the base, which contains the detonating arrangement, being strengthened by an iron disc.

"The bullet is made of an alloy of 12 parts lead and 1 part tin. It has two cannelures, is papered, and lubricated with beeswax. The weight of the bullet is 480 grains.

"The case is made of sheet-brass, 0·004 in. in thickness, partially covered on the inner side with tissue paper attached by cement. It has also a small band of sheet-brass, 0·004 in., riveted on its inner side in such a position that when the case is rolled up it will be between the

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* Although Mr. Henry had obtained the prize for breech-action, Mr. Martini proved more successful at the second competitive trial, as he then used central-fire gas-tight cartridges, which he did not possess at the first trial. Full details of the competition will be found in "Rifled Breech-Loaders and their Ammunition," by Major Majendie and Captain C. O. Browne.

† The infantry rifles adopted by the armies of Europe are as follows:—

England has the Martini-Henry; Prussia, the Mauser; Bavaria, the Werder; Austria, the Wendl; Italy, the Wetterli; Holland, the Beaumont; Russia, the Berdan; Servia and Roumania, the Peabody; Spain, Sweden, and Denmark, the Remington; and France the "Fusil gras," to which the Chassepôt can be converted. (See article on the subject in "Colburne's Magazine," September 1875).

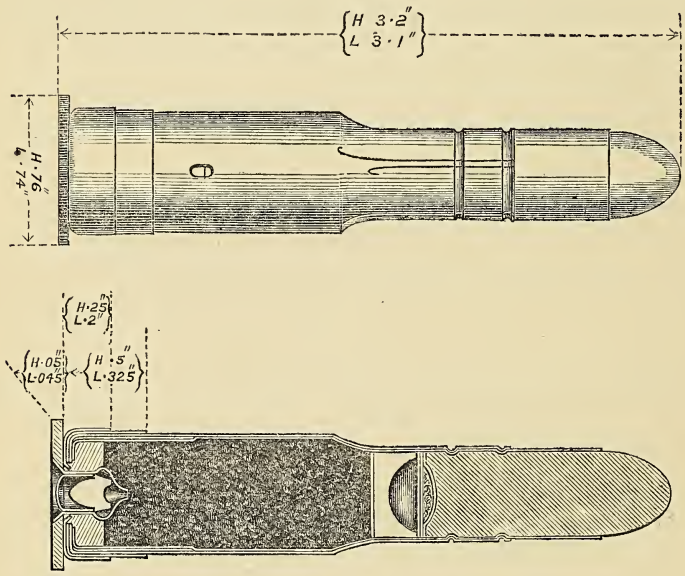
folds, so as to prevent "cutting" at the top of the base cup. There is a small hole pierced through the case, in order that it may be seen if the band is in its proper position. After the case is rolled, the top end is reduced in diameter by crimping from ·577 in. to 0·45 in.

"The charge of powder is 85 grains; the manufacturing limit being ± 2 grains. On the top of the charge is a glazed-board disc, with a concave beeswax wad attached, on the top of which two more glazed-board discs are placed; the bullet is then inserted, and secured by choking the case into the two cannelures.

"The remaining parts of the cartridge are the same as in the cartridge for the Snider arm."

Martini-Henry Cartridge, Mark III.

(Full size.)



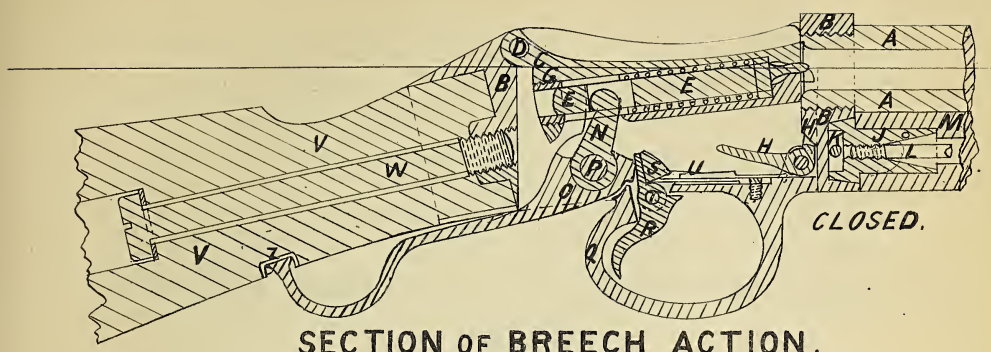
(For the weights of packages of small-arm cartridges, see Table II.)

Manufacture of Small-arms.

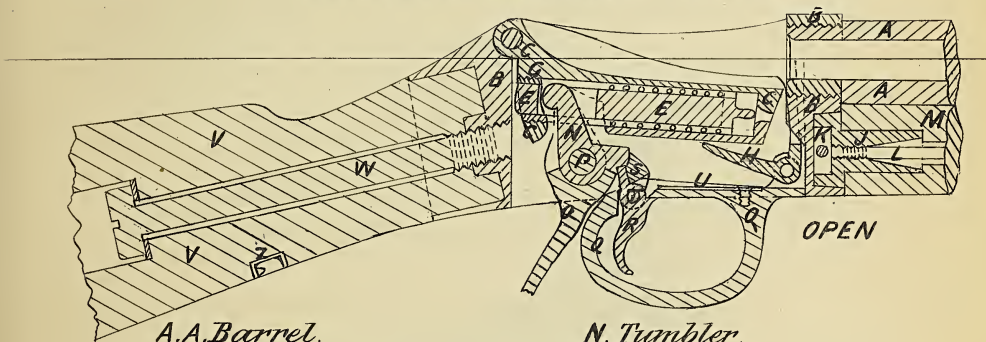
The Martini-Henry is the only rifle now made by Government. It is manufactured at the Royal Small-Arms Factory, Enfield Lock.

As many of the parts as possible are, by means of fixed machines, made interchangeable—as was the case in the Enfield rifle—in order to facilitate repair. The parts, therefore, undergo a regular system of viewing, gauging, and marking in process of manufacture, so as to ensure "interchangeability." The Small-Arms Factory can supply

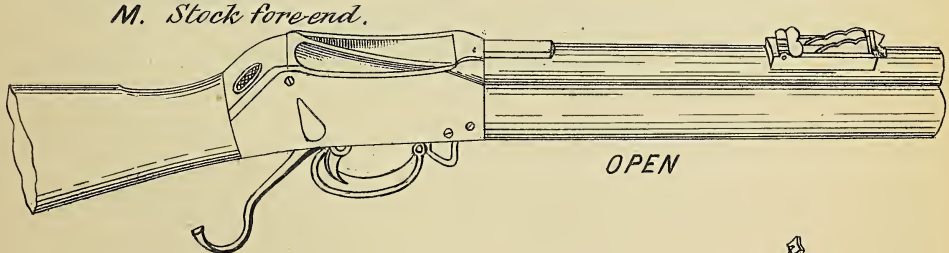
MARTINI-HENRY RIFLE.

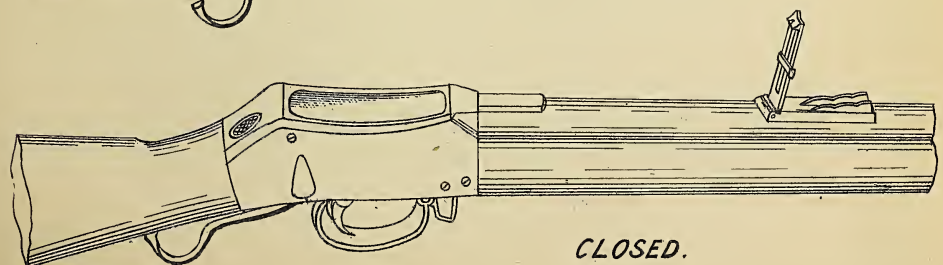


SECTION OF BREECH ACTION.



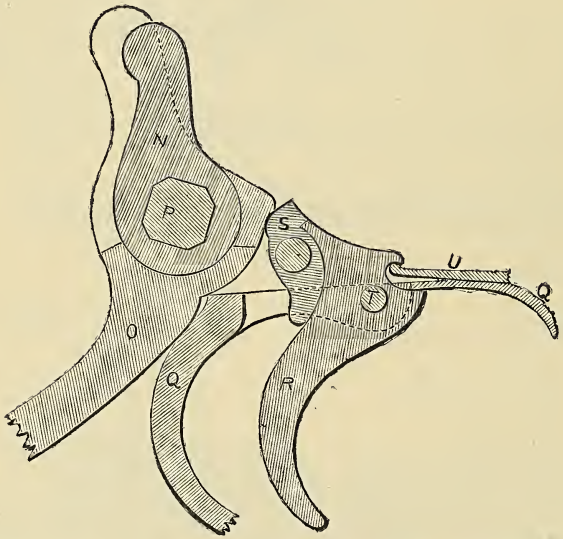
A.A. Barrel.
B.B. Body.
C.C. Block.
D. Block axis-pin.
E. Striker.
F. Main spring.
G. Stop-nut.
H. Extractor.
I. Extractor axis-pin.
J. Rod & fore-end holder.
K. Rod & fore-end holder screw.
L. Ramrod.
M. Stock fore-end.
N. Tumbler.
O. Lever.
P. Lever & tumbler axis-pin.
Q. Trigger plate & guard.
R. Trigger.
S. Tumbler rest.
T. Trigger & rest axis-pin.
U. Trigger & rest-spring.
V. Stock-butt.
W. Stock bolt washer.
Z. Lever catch bolt,





SECTION OF PRESENT PATTERN TRIGGER ACTION.

(Full size.)



NOTE.—The section of the breech action of the Martini-Henry rifle on the preceding page shews the tumbler, tumbler rest, and trigger, as arranged in the experimental arms issued to the troops. The sketch annexed shews the modified arrangement adopted in the service arm.

3000 rifles a week; were more required in case of an emergency they could be obtained from private gun-makers, but they would be gauged by the Government viewers, in order that the various parts should be interchangeable with those made at Enfield.

Bayonets and ramrods are also manufactured at Enfield.

(*Swords*—see Table III.—and *pistols* are procured from the trade, but tested by Government viewers).

The bands, nose-cap, heel-plate, swivels, &c., &c., are called the furniture of an arm.

Putting all the parts together is called "assembling," and taking them asunder is called "stripping."

The Stock is made of walnut—a wood light, tough, and close of grain, durable, and not liable to warp. The stocks come principally from Italy, and are supplied in the rough at Enfield by the contractor.

The wood on arrival is examined, and must be perfectly free from (1) "shakes," caused by the action of the wind on the heavy branches, (2) knots, (3) "galls," arising from injury to the bark, (4) cross grain, (5) fly-holes, and (6) injury by sea water.

Fly-holes, though like minute pin-holes on the exterior, may lead to considerable cavities inside, where the fly has grown and lived. A fly is preserved at Enfield which was known to have been five years in a stock.

The injury by the sea water is detected by discoloration, and tested by nitrate of silver, which forms a white precipitate with the chloride of sodium, or common salt.

All the other defects weaken the stock itself, but damage by sea water affects the barrel, as the salt causes it to rust.

The stock for the Martini-Henry is in two parts—the butt and the fore-end. (They are joined by means of the body of the lock, to which they are attached by screw bolts). Those required for the repair of the Snider and other arms are, of course, full length.

All stocks must be seasoned or desiccated, to obviate warping.

The older a tree is the less seasoning it requires, as it is naturally dryer than a younger tree; so the time of seasoning varies from one to two years. Seasoning is effected by simply stacking the stocks in well ventilated rooms in such a manner that the air can permeate the stacks. The windows of the building are closed in damp weather, and the stocks are always kept free from dust and insects.

Should time be an object desiccation is employed, by which means the stocks are ready for use in six weeks. This is accomplished by placing the stocks, one by one, on tiers of benches in a chamber into which a constant stream of hot air—from 80° to 90° Fahr.—is allowed to enter at the ceiling and escape at the floor.

The parts of the stock being properly dried, are readily brought to correct size and shape in copying lathes.

The Lock.—The Martini lock, or breech-action, consists principally of the "body," which encloses the whole; the "block," which closes the breech and contains the "striker" and its "main spring;" the empty cartridge extractor, the tumbler, tumbler rest, trigger, trigger

guard, and lever. Most of these parts are of wrought-iron, being blocked out from a bar; that is, the end of the bar is brought to a white heat, and placed under a Nasmyth's hammer, the anvil and hammer of which are reciprocally recessed to the shape of the article required.

The article, thus roughly forged, is brought by a series of machine operations to exact size, shape, and finish; for example, the trigger guard undergoes clipping, slotting, milling, drilling, &c., &c.—in all, over 70 operations—before it passes into the final viewer's or gauger's hands.

The trigger guard furnishes us also with an illustration of "blueing" —an operation which it and the "body" (steel), as well as the bands and nose-cap of the stock, finally undergo, for the purpose of making them not liable to rust. It consists, simply, in coating the surface with a thin film of oxide, which is effected by heating the article in a sand bath until it assumes a dark-blue colour. The parts which are exposed to hard usage or friction—namely, the lever and block (as also the heel-plate of the stock)—are "case-hardened"; *i.e.*, hardened on the outside by means of heating with some substance containing carbon. At Enfield the article is put in a cast-iron pan filled with bone-dust, heated to redness, and allowed to cool, by which time it has assumed a mottled appearance.

The Main Spring is made first by winding the soft steel wire round a cylinder furnished with a raised helix, then heating the spiral thus formed to redness and suddenly cooling it, and then tempering it in the usual way—*i.e.*, raising it to a certain heat (in this case until it would cause oil to flash) and allowing it to cool naturally. This spiral spring is submitted to the following tests before it is passed for use:—

1. It is placed in a cramping machine for 15 hours, to ascertain if it is of the proper temper. If too hard it would break, if too soft it would become reduced in length.

2. It is subjected to a weight of 40 lbs., which reduces it to a length of 1 in. from $1\frac{3}{4}$ ins., and which is 3 lbs. more than it has to bear when at "full cock" in the gun.

3. It is placed in a machine, and undergoes the strain and motion of firing 500 rounds.

The spiral spring was supposed to be a weak element in the Martini lock; but when thus tested it stands its work remarkably well, and even if it does become unserviceable it can be replaced with great ease.

The Striker is also of tempered steel. When made, the point is, as a test, hammered through a sheet of copper several times, to ascertain that it will neither break nor bend in actual use when striking the copper cap in the base of the cartridge. It also can be easily replaced if necessary.

Action.—The lever, on being pulled up, not only raises the block so as to close the breech, but in doing so compresses the spiral spring to full

cock. When the trigger* is pulled the spring is released, and forces the striker forward on to the cap in the cartridge. When the lever is pulled down the block falls, and in doing so opens the breech and strikes against the lower limb of the extractor (a bent lever), and causes it to eject the empty cartridge by means of the catches on its upper limb, which work against the projecting iron base of the cartridge.

The Barrel of the Martini-Henry is of steel—a metal which, owing to its greater strength, elasticity, and hardness, is much superior for the purpose than the wrought-iron hitherto used. The old objections to steel were its brittleness and the difficulty that existed in welding on the nipple lump. Neither of these objections exist any longer; the latter being removed by the introduction of breech-loaders, and the former by improvements in the manufacture of steel to such an extent that not one in 50,000 finished barrels fails at the proof—which consists of one round with a double charge of powder and a bullet equal in weight to 1½ the service bullet. The steel is supplied by the contractor in rough barrels—simply cylinders of sufficient size, with a hole through the centre.

The rough barrel undergoes the following principal operations:—

1. Boring.	4. Chambering.
2. Turning.	5. Gauging.
3. Rifling.	6. Sighting.

The boring is done gradually, the concentricity and regularity of the work having to be repeatedly tested by "shading"—*i.e.*, holding up the barrel to the light and noticing the appearance of the shadow thrown down the bore by a black board at the top of the window. Any irregularity in the barrel would be indicated on the edge of the shadow.

Turning is cutting off the exterior surface, and is performed in a lathe; the barrel being kept steady to the action by bearings in solidified resin, which is poured around it when in a liquid state and is easily knocked off when the operation is over.

Rifling is performed in a machine furnished with a tangential bar which guides the cutter bar down the bore at the proper angle of the rifling. As the grooves are "progressive" for 11 ins.—that is, deeper at the breech than towards the muzzle—there is an arrangement by means of which the cutter is screwed gradually down as it cuts its way up the bore for that distance, after which the depth remains the same throughout.

The barrel is rifled with 7 grooves, ·03 in. of the original bore being left between adjacent grooves as lands, so that a section of the rifled bore presents the appearance of a heptagon with acute re-entrant angles.

The twist of the rifling is 1½ in the length of the bore, or 1 turn in 22 ins., and there is a machine for testing the spiral.

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* The trigger "pull-off" is equivalent to a weight of 6 to 8 lbs. (See clause 144 Army Circular, 1st October, 1875.)

"Chambering" is enlarging the breech in the barrel sufficiently to receive the bottle-shaped cartridge.

Gauging.—The calibre of the finished barrel is ·45; a plug of ·452 should not pass down.

The foresight is slipped into an undercut recess on the barrel, and is brazed on. The hind-sight is soldered on the barrel, having been fixed into a frame attached to which are pointers that determine the true position of the sight.

The barrel is, of course, viewed through the several stages of its manufacture, and when finished bears several viewers' marks stamped on it, including the proof marks, and, last of all, W.D. and the broad arrow—which indicates it has been finally approved for service.

The Ramrod, or rather cleaning rod, is altogether of steel, and has a short screw-thread on the end to receive the brass jag.

The Bayonet is also made at Enfield. The blade is of steel, tempered in a bath of lead (617° Fahr.), and the remainder wrought-iron. With Martini-Henry rifles, the ordinary '53 bayonet (altered in the socket) is issued for the rank and file, the sword-bayonet for serjeants and rifle regiments, and the cutlass sword-bayonet for the navy. (See paras. 2659 and 2713 "List of Changes in War Matériel," 1874–5).

Storing, Examination, and Repairs.

At home, the service small-arms are stored in large quantities at the Tower of London, and there are reserves held at all stations, particularly at Weedon.

All small-arms, whether from the Government factories or supplied by the trade, are sent into store fit for immediate issue. Arms returned by the troops are examined locally for assessment of damages, and at some few stations are repaired. They all, however, eventually find their way back to the Tower, where they are subjected to a thorough examination by officials from the Royal Small-Arms Factory. Damages are assessed where necessary, and the arms are classified according to regulation. Slight repairs are effected on the spot, before being returned into store; but should a defect be extensive, the arm is forwarded to the Royal Small-Arms Factory, Birmingham—another branch of the Royal Small-Arms Factory, Enfield. Weapons which are not worth repairing are sold by auction.

With regard to storing small-arms abroad or at out-stations, care must be exercised in choosing a storehouse which is altogether free from damp. If the arms are in chests they should be examined at least every six months, to see that they are fit for immediate use; if they are placed in racks they should be frequently dusted, and thoroughly dried and oiled every six months.

All arms in store are classified under the heads of "serviceable," "repairable," or "unserviceable." Rifled breech-loading arms of the bores ·45 and ·577 are further distinguished as follows:—

Class I.—New arms, and used arms which may have had slight repairs only, and are equal to new.

Class II.—Used arms that have been thoroughly repaired.

The Reserve.—Arms that can be repaired and made fit for issue in case of emergency.

All the Martini-Henry in the regular service may be considered as belonging to Class I. (See clause 115 Army Circular, War Office, 1st August, 1875).

When a commissary receives new arms they must be examined, to ascertain—1st, that they have received no injury in packing; 2nd, that they have not been damaged in carriage by damp or salt water; 3rd, that the barrels and locks are not clogged with oil.

When arms are returned into store, great care is required in their examination, particularly when repair is contemplated; and great judgment is required in repairs, so as to render arms serviceable at the cheapest rate but yet in an efficient manner. In order to thoroughly examine an arm, strip it, or take it to pieces, and examine stock, lock, and barrel separately.

Stock.—The stock is examined for bruises, cracks, and breakages—for the latter chiefly in the fore-end.

Bruises on a stock, unless very deep, are repaired by wetting the walnut and holding a hot iron on the spot. This raises the wood, and when the stock is cleaned and polished the injured part is scarcely perceptible. Slight dents and bruises are scraped and filed out, and polished over.

If the fore-end of the stock be cracked or broken, it is repairable by fitting and glueing on either a short or long splice, (supplied to armourer-serjeants), according to the position of the defect.

If the edge of the barrel groove is merely broken, it can be easily repaired by a piece of wood dovetailed in from the inside in such a manner that it cannot be pushed out, while the barrel will prevent it from being pushed in.

A stock broken at the toe of the butt can be repaired by glueing on a new piece, unless the fracture extends to the screw-hole of the butt-plate.

Lock.—The lock is examined for freedom from rust, and the proper action of its various parts. It is generally repaired by renewing an injured part. The main-spring of the Enfield (percussion) lock may be weakened by filing it at the bend, or strengthened by heating it and "re-setting" it. The bents of the tumbler may be deepened by filing, and the nose of the sear adjusted in the same manner. It is necessary to adjust the pull-off.

Barrel.—All arms which have been on service are more or less affected with rust where the barrel beds in the stock; and when this prevails to any extent, no matter how carefully cleaned, the rust will in a short time show itself again, and ultimately render the arm unserviceable. Arms so damaged should be put aside for re-stocking. The other common defects are rust inside, enlargement of the bore, dents, bulges, bends, and damaged sights.

To examine a barrel on the inside, clean it first with tow thoroughly and look up at the light through it with the eye about 3 ins. from the

barrel. Should rust have eaten in too deeply it cannot be repaired, but otherwise it may be repaired by the process of "leading," or by "lapping."

Plugs are issued to test enlargement in the bore—which is more likely to be found in wrought-iron than in steel barrels. Should the rejecting plug pass into the bore, it does not follow that the barrel should be condemned, unless at trial at a target the shooting of the piece is found to be wild or unsatisfactory.

A dent can generally be repaired, but a bulge cannot.

Wrought-iron barrels are frequently bent from the soldiers using their rifles for slinging or carrying weights over their shoulders. Barrels so damaged can be straightened again.

The sights, if broken, can be renewed.

As to the furniture and cleaning rods, broken parts should be renewed.

All minor repairs of arms in use—such as furbishing, cleaning, browning, repairing locks, and supplying deficient parts—are executed by armourer-serjeants, who must perform free of charge all repairs required to the arms (including lances, pistols, swords, and scabbards) in possession of their respective corps; and to this end they will examine and clean them periodically, and brown the barrel of each rifle every second year, or oftener if necessary.

The sums to be levied against a regiment or corps on the return of arms into store will be only for the cost of such repairs as ought to have been executed by the armourer-serjeant, or for the repair of damage done through carelessness or intentionally.

Not only a forge and set of tools, but a box containing a certain percentage of the various parts of rifles, pistols, swords, &c., are supplied at the public expense to armourer-serjeants of the regular service for the repair of arms.

A complete list of these articles, interchangeable and non-interchangeable, together with general instruction for the repair of arms, will be found in the Royal Warrant and "Regulations for the Equipment of Her Majesty's Army," Vol. III., 1870; and the cost of the various parts of the arms will be found in the "Priced Vocabulary of Stores used in Her Majesty's Service, 1875."

The following "Instructions for Armourers," signed by Lieut.-Col. Close, R.A., Supt. Royal Small-Arms Factory, have recently been issued by the War Office:—

CARE, REPAIR, &c., OF THE MARTINI-HENRY RIFLE, MARK I.

1. All parts connected with the breech action should be kept perfectly clean; but all cutting substances, such as emery, sand-paper, &c., are to be strictly avoided in cleaning. The buff stick must not be used to any part of the action.

2. Oil only should be used in cleaning the parts.

3. Care must be taken not to injure the face of the block in cleaning, especially the striker hole.

4. A damp rag, flannel or tow, is all that is usually required to clean the barrel out. If much water is used, it is liable to run into the action. The butt should be raised when washing out. After washing out, an oily rag or flannel should be

used. On many occasions the oily material may be found to be efficacious without the previous use of water.

Directions for stripping the Action.

1. Close the action.
2. Knock out the block axis pin by placing a drift on the slit-head of the pin, first removing any dirt there may be in the slit.
3. Depress lever, and hold down front end of block with left thumb, close the lever, and the block will spring out.
4. Take out block, turn the curve in keeper screw fair with the curve in the stop nut, unscrew the stop nut; the striker and main spring will then fall out.
5. Turn the keeper screw head of lever axis fair with axis hole, press out axis pin, and take out the tumbler.
6. Turn out extractor axis screw, and remove extractor, trigger guard, and lever.
7. Turn out the screw holding the trigger spring, and take out the spring.
8. Turn out axis screw of tumbler rest and trigger, take out tumbler rest and trigger.

Directions for stripping Furniture, Barrel, and Stock.

9. Draw cleaning rod, first turning the rod so that the cam is against the rod-holder. The rod will then draw straight out; and in no case is the rod-head to be pulled with any force away from the barrel.
10. Remove upper band and barrel stud pins.
11. Partly unturn band screws and take off bands. The lower band stop pin should not be removed.
12. Drive fore end of stock off barrel stud at breech end with wood drift.
13. Take off butt plate.
14. Turn out stock bolt, and take off butt of stock.
15. Grip barrel in gun-metal clam, the under clam to receive the barrel stud. Unscrew body with breech wrench (in no case should this be attempted without previously removing the extractor).

Oil should be applied to the following parts of the Martini action occasionally :—

Knuckle and knuckle seat of block.
Axis pin of block.
Lever ends and seat in block.
Lever and tumbler axis.
Tumbler rest axis.
Tumbler rest and tumbler bearing surfaces.
Trigger axis.
Trigger nose and spring.
Extractor axis.
Main spring, striker.
Stop-nut and tumbler.

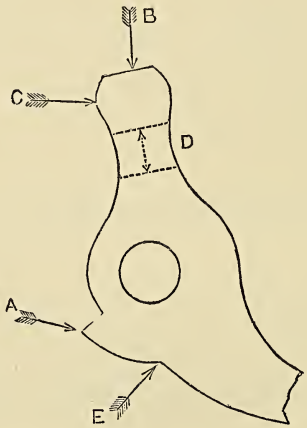
Directions for assembling Action, Barrel, Stock, and Furniture.

1. Grip barrel in gun-metal clam, screw on body until the flat on the barrel is at right angles to the sides of the body, for which purpose use the breeching square.
2. Replace butt of stock, observing that the stock bolt washer is in its place in the stock butt, screw up stock bolt.

3. Screw on butt plate.
4. Slide fore end of stock on barrel stud.
5. Replace bands and turn home band screws.
6. Replace upper band pin.
7. Replace barrel stud pin.
8. Replace cleaning rod. When the rod is in its proper position, the cam is away from the rod-holder.
9. Place trigger and tumbler rest in guard, and screw up axis screws.
10. Replace trigger spring, taking care that the nose of the trigger spring is under the trigger; screw in the trigger spring screw.
11. Place lever and tumbler in trigger guard, slide guard with lever and tumbler into the body, and replace axis pin with indicator pointing upwards, in the direction of the block axis pin, and screw round keeper screw head to its proper bedding.
12. Replace extractor and turn in axis screw.
13. Place striker in block and drop in main spring, screw home stop nut, and turn keeper screw-head into its bedding.
14. Turn striker round until the wider side of slot is downwards.
15. Place the block in body with the front end lowest; hold the lever with right hand, the thumb pressing the indicator forward, the trigger being pressed back by the fore finger; press hard on the knuckle of block with the heel of the left hand to force it into its seat; at the same time depress and work the lever to get the tumbler into the slot in the striker.
16. Compress the sides of the block axis pin, preparatory to placing it in the body. Place it in the body.

Replacing Components, Martini-Henry Rifle, Mark I.

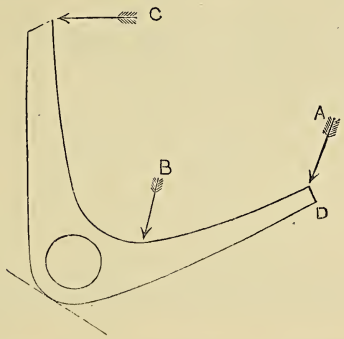
1st. Loading Position.—If the block be too high, the bearing surface at *A* of the lever may be depressed by means of a punch to the breadth of the corresponding surface on the tumbler. If an adjustment of more than ·01 of an inch is required, a new lever should be fitted.



2nd. Should the block be too *low*, an amount *not to exceed* ·01 in. may be *added* to the bearing surface at *A* by carefully drawing out the metal at that point; but should *more than* ·01 in. be required (which will rarely, if ever, be the case), a *new* lever should be fitted.

3rd. Firing Position.—When the block is in the firing position, should the striker strike the cap *too high*, an amount *not exceeding* ·01 *in. taken off* the bearing surface of the lever horns at *B* will be sufficient to rectify the error.

4th. Should the striker strike the cap *too low*, the horns of the lever may be drawn out between the lines indicated at *D* not to exceed ·01 in., care being taken not to spread the horns or set them out of position at *C*.



Extractor.—When the block is at the loading position the point *A* should be just free from the underside of the block.

When the block is depressed to the lowest position it should bear on point *B*, holding the extractor firm; but should the lever at *E* touch the guard so as to prevent the block doing this, the guard may be filed to allow the lever to be clear.

The point *D* should be on the trigger when the extractor is at its lowest position; if it will not bed down, the fault must be looked for on the head of the trigger spring screw; if this stands too high, it should be filed flat.

Trigger.—In replacing a trigger, care must be taken not to *shorten the nose* in adjusting the pull off, as *this affects the loading position of the block*. The trigger pin should be a close fit, as the correctness of the "pull-off" chiefly depends upon it.

Trigger Spring.—In replacing a trigger spring, care must be taken that the head of the screw beds well down on the spring, and that the point does not bear on the guard swivel screw.

Tumbler Rest.—In replacing a tumbler rest care must be taken *not* to file away the bent in adjusting the pull off, *as this affects the loading position of the block;* the front edge of bent should be slightly rounded to free it from burrs.

Tumbler.—In replacing a tumbler, it should *pass firmly* on to, but *not be driven hard* upon, the squares of the axis pin; it should also work freely between the horns of the lever.

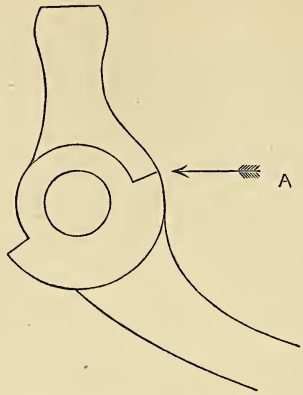
Indicator.—Remarks same as upon tumbler.

Lever.—In replacing a lever, the bearings at point *A* should be free when the lever is depressed; otherwise it prevents the block from having its *full fall*.

The end of the lever must be set to drop freely into the lever catch block; care must also be taken that the lever beds on its seat at the under side of socket end of body.

The levers issued with the spare parts are for short butts—they will require setting for long butts—a slight blow with a mallet is all that is required to make them drop freely into the lever catch block; the levers for short butts are issued in preference to levers for long butts, as the adjustment required by the former to fit

them to long butts is more simple than to adjust a lever for a long butt to a short butt.



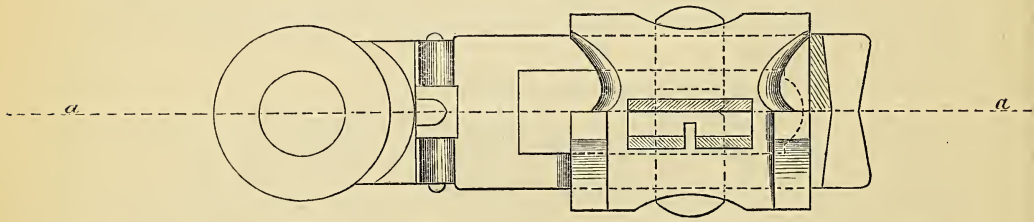
Striker.—When replacing, care must be taken that the larger part of the slot is downwards.

Stock.—To replace a stock the butt plate must be removed, the stock bolt unscrewed, and washer removed. Should the new stock not be drawn firmly home when the bolt is screwed up, a second washer must be put on. Should the point of the stock-bolt protrude on the inside of the body, it will interfere with the full play of the block when extracting; additional washers may require to be added in a soft sap stock to prevent this.

Easing Springs.—The correct mode of easing springs is to hold the rifle by the left hand, thumb of right hand on front end of block, pulling the trigger with the forefinger of right hand, allowing the block to close slowly without jar. In no case must the lever be touched.

Directions for Renewing Lines on Sight Slides and Caps.

Fit the sight-line tool over the slide and leaf, and press it up to the cap; then with a scriber, having a point of the proper width, re-mark the windage and centre lines on the slide and cap, as shewn by the dotted lines *a a* in sketch. Reverse the tool and re-mark the opposite windage line, and trace over the centre lines *a a*, to prove that they are in the centre, as there is a slight variation in the width of the leaves.



When a spare part which bears *a date of manufacture* is placed in a rifle, the date on which this spare part is so used is to be placed by the armourer near the *S* which will be found on the spare part.

Table I.

Table of Central-Fire Breech-Loaders.

	Weight of arm without bayonet.	Length of arm without bayonet.	Barrel.					Ammunition.			Arm sighted to	To what corps issued.
			Weight.	Length.	Calibre.	No. of grooves.	Twist of rifling.	Charge.	Bullet.	Remarks.		
	lbs. ozs.	ft. ins.	lbs. ozs.	ft. ins.	in.		ins.	grs.	grs.		yds.	
Martini-Henry	8 12	4 1½	3 6	2 9⅕	·45	7	1 in 22	85	480	Serjeants carry 40 Martini-Henry rounds each, and rank and file 70. The same blank cartridge suits Snider and Martini-Henry arms.	1400	Guards, Infantry of the Line (including the Rifle Brigade), Royal Marines, and Royal Navy.
Snider converted. Enfield rifle, long	9 0	4 7	4 10½	3 3	·577	3	1 in 78				950	Militia and Volunteer Corps, and some N.I. Regts. India.
Snider converted. " short	8 12	4 0½	4 8¼	2 9	·577	5	1 in 48				1000	Royal Marine Artillery, and serjeants of Militia and Volunteer Corps, and some N.I. Regts. India.
Snider converted. Artillery carbine*	7 7	3 4¼	3 6¼	2 0	·577	5	1 in 48	70	480		600	Royal Artillery, Army Service Corps, Militia and Volunteer Artillery.
Snider converted. Cavalry "	6 10¼	3 0⅞	3 2¾	1 9⅝	·577	5	1 in 48				600	Cavalry Regiments, except Lancers.
Snider converted. Lancaster* "	8 1¾	3 11½	4 2¼	2 7½	·577 to ·593	oval bore.					—	Royal Engineers.

* It is probable that the Royal Artillery, Engineers, and Army Service Corps will shortly be supplied with the Martini-Henry rifle.

Table II.

Packages of Cartridges, S.A., Breech-Loading.

(Copied from R.L. Table, 12th May, 1875.)

Package.		Average tare.	Ball, B.L. Snider Arm, Mark IX.		Ball, B.L. Martini-Henry Arm, Mark III.		Blank, B.L. 2½ drs., Mark IV.		Blank, (converted), B.L. 2½ drs., Mark IV.		Ball, Pistol, R. Revolver, Adams B.L. Mark I.		Ball, B.L. Buck Shot, Snider Arm, Mark II.		Ball, B.L. Gatling, ·45 Bore, Mark I.		Ball, B.L. Gatling, ·65 Bore, Mark I.	
Name.	Dimensions, external.		Rounds.	Gross.	Rounds.	Gross.	Rounds.	Gross.	Rounds.	Gross.	Rounds.	Gross.	Rounds.	Gross.	Rounds.	Gross.	Rounds.	Gross.
		lbs. oz.		lbs. oz.		lbs. oz.		lbs. oz.		lbs. oz.		lbs. oz.		lbs. oz.		lbs. oz.		lbs. oz.
Bundle	—	—	10	1 $0\frac{10}{16}$	10	1 $1\frac{14}{16}$	10	0 4	10	0 $5\frac{6}{16}$	12	0 $8\frac{3}{16}$	10	0 15	10	1 $2\frac{1}{4}$	10	3 $7\frac{3}{16}$
Barrel, cartridge — Half	L. $16\frac{9}{16}$ D. $13\frac{4}{16}$	12 2	—	—	—	—	2000	62 2	2000	79 5	—	—	—	—	—	—	—	—
Barrel, cartridge — Quarter	L. $14\frac{1}{4}$ D. $11\frac{6}{16}$	7 12	700	81 4	700	86 0	1300	40 4	1300	51 7	—	—	760	79 0	750	93 5	230	87 1
Box, wood, ammunition, small-arm — With tin lining — Adams revolver... II.	$11\frac{3}{4}$ by 8 by $4\frac{1}{4}$	4 7	—	—	—	—	—	—	—	—	600	30 1	—	—	—	—	—	—
Box, wood, ammunition, small-arm — With tin lining — Bullock ..... I.	$20\frac{1}{2}$ " $10\frac{1}{4}$ " $9\frac{3}{8}$	16 8	780	98 0	840*	110 5*	1320*	49 8*	1320*	60 13*	—	—	—	—	—	—	—	—
Box, wood, ammunition, small-arm — With tin lining — Camel..... I.	$27\frac{1}{4}$ " 14 " $13\frac{3}{8}$	33 1	2400	284 9	2600*	323 9*	4130*	136 5*	4130*	171 13*	—	—	—	—	—	—	—	—
Box, wood, ammunition, small-arm — With tin lining — Special	$27\frac{1}{4}$ " 14 " $12\frac{1}{8}$	31 7	2000	239 4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Box, wood, ammunition, small-arm — With tin lining — S. pattn. ..... I.	$16\frac{1}{4}$ " 7 " $8\frac{1}{2}$	9 0	420	52 8	480	62 10	740	27 12	740	33 14	1680	80 10	420	48 6	500	66 0	160	64 3
Box, wood, ammunition, small-arm — With tin lining — S. pattn. III. or IV.	22 " 7 " $8\frac{1}{2}$	12 4	560	70 4	600	79 4	960	36 4	960	44 8	—	—	—	—	680	89 13	200*	81 4*
Box, wood, ammunition, small-arm — Without tin lining ..... I.	$16\frac{1}{4}$ " 7 " $8\frac{1}{2}$	7 10	420	51 2	480	61 4	740	26 6	740	32 8	1680	79 4	—	—	500	64 10	160	62 13
Case, wood, powder, metal lined. — Half	$14\frac{1}{4}$ " $13\frac{1}{2}$ " $16\frac{3}{4}$	30 0	1440	181 0	1540	202 0	2400	90 0	2400	110 10	5364	258 12	—	—	—	—	—	—
Case, wood, powder, metal lined. — Quarter..	11 " $10\frac{1}{4}$ " $13\frac{3}{4}$	18 0	560	76 0	660	91 11	1020	43 8	1020	52 5	2220	112 11	—	—	—	—	—	—

Ball, Pistol, R. Revolver, Colt B.L., Mark I.—Gross weight of 18 rounds, $6\frac{10}{16}$; gross weight of 2250 packed in quarter case, M.L., 69 lbs. 12 oz.
Blank, B.L. Cases, for proof, Snider Arm.—Gross weight of 10 rounds, $7\frac{5}{16}$ oz.; gross weight of 850 packed in quarter barrels, 46 lbs. 9 oz.
Bullets are issued in packing cases containing 500 each. Empty cartridge cases are issued in packing cases containing 500 each.

* These figures are not service packages. S.A.A. boxes, if made of teak, may weigh a few ounces heavier.

TABLE III.—*Table of the Lengths, Weights, &c., of the Swords used in the British Service.*

	Description.	Length of blade.		Weight of sword.		Weight of scabbard.		Total weight.		Remarks.
		ft.	ins.	lbs.	oz.	lbs.	oz.	lbs.	oz.	
1	Sword, pattern 1853 (for all heavy and light cavalry and other mounted corps)	2	11½	2	7¾	2	1¼	4	9	The Household Cavalry have a special sword.
2	Sword, pattern 1864, do., do., do.	2	11½	2	7¾	2	1¼	4	9	No 2 will gradually supersede No. 1. The blade is the same, but the hilt is solid, of homogeneous steel, the weight so arranged as not to disturb the balance when it is fitted to swords of No. 1 pattern. The scabbards are of iron lined with wood.
3	Sword, pattern 1856, for Staff Serjeants, Royal Artillery	2	8½	1	12¼	1	3	2	15¼	
4	Sword, pattern 1862, for Staff Serjeants, Royal Engineers	2	8½	1	14½	1	3	3	1½	In 1866 the blades of the Staff Serjeants' swords, of Line and Rifle Regiments, were assimilated to those of the Staff Serjeants, Royal Artillery and Royal Engineers. The hilts of the swords and the mountings of the scabbards are of steel, for Artillery and Rifles, and gilt for the Engineers and Line. The scabbards of the Artillery and Engineers are of iron, of the Line and Rifles of leather.
5	Sword, pattern 1866, for Staff Serjeants, Rifle Corps*	2	8½	1	12¾	0	13½	2	10¼	
6	Sword, pattern 1866, for Staff Serjeants, Infantry of the Line	2	8½	1	15½	0	14	2	13½	
7	Sword, for Staff Serjeants, Highland Regiments	2	8½	2	11¾	0	12½	3	8	The Claymores have leather scabbards, the hilt and mountings of steel; the scabbards of Staff Serjeants of regiments wearing the trews have top and centre ring lockets and a shoe to the tip of the scabbard.
8	Dirk, for Drummers, Pipers, Band, and Highlanders	1	0	0	12½	0	7	1	3½	Drummers' swords and scabbards are brass mounted for Line Regiments, and iron mounted for Rifles.
9	Sword, pattern 1857, for Drummers and Band, Line Regiments*	1	7½	1	14	0	10	2	8	The Pioneers' sword has a saw back, leather scabbard, and brass mountings.
10	Sword, pattern 1858, for Buglers and Band, Rifle Regiments*	1	7	1	13	0	8½	2	5½	The blade of the last pattern naval cutlass is identical with that of the cutlass sword bayonet. Naval cutlasses have leather scabbards with brass mountings and a spring inside to prevent the cutlass falling out.
11	Sword, pattern 1856, for Pioneers	1	10½	2	4¼	0	12	3	0¼	Militia Artillery Buglers carry a special hilt sword bayonet.
12	Cutlass, for Royal Navy	2	1½	2	5	0	12	3	1	
13	Sword, for Staff Serjeants, Army Hospital Corps and Reserve Forces	2	8½	1	14¾	0	13¼	2	12	Except Militia Artillery and Rifles, brass hilt with leather scabbard.
14	Sword, Army Hospital Corps, Serjeants	2	4½	1	7½	0	7	1	14½	Brass hilt, with leather scabbard brass mounted.
15	Do., do., Privates	2	2½	2	2½	0	7	2	9½	* Also for Militia.

WOOLWICH,
1st October, 1875.

THE APPLICATION OF PROFESSOR BASHFORTH'S GENERAL TABLES TO PROBLEMS IN PRACTICAL GUNNERY.

BY

CAPTAIN J. SLADEN, R.A.,

PROFESSOR OF ARTILLERY, R.M. ACADEMY.

THESE General Tables are applicable to any elongated projectile with an ogival head, when its weight and diameter are known.

Let d = diameter of projectile in inches,

w = weight of do. in lbs.,

s = range in feet.

Then $\frac{d^2}{w} \cdot s$ = *reduced range* (Table I.),

and if t = time of flight in seconds,

then $\frac{d^2}{w} t$ = *reduced time* (Table II.)

EXAMPLES.

(1) With what velocity would a 9-in. shell, fired with a battering charge of pebble powder, strike a target at 1000 yds.? (The muzzle velocity is 1420 ft. per second.)

d = diameter of shell in inches = 8·92 ins.,

w = weight of shell in lbs. = 250 lbs.,

s = 1000 yds. = 3000 ft.

Hence, *reduced range* $= \frac{d^2}{w} \times s = \cdot 3183 \times 3000 = 954 \cdot 9$ ft.

Now, corresponding to velocity 1420 in Table I. we find

	ft.
	1251·1
Adding reduced range,	954·9
	2206·0

which, by an inverse process in the same table, corresponds to a velocity of 1240 f.s., nearly.

Hence, striking velocity at 1000 yds., is 1240 ft. per second.

(2) With what velocity would a 9-in. shell, fired under the above conditions, be travelling at the end of 3 secs.?

Here, $\textit{reduced time} = \frac{d^2}{w} t = \cdot 3183 \times 3 \text{ secs.} = \cdot 9549 \text{ secs.}$

Now, corresponding to velocity 1420 in Table II., we find

	sec.
	·8057
Adding reduced time,	·9549
	1·7606

which, by an inverse process in the same table, corresponds to a velocity of 1194 f.s., nearly.

Hence, remaining velocity after 3 seconds' time of flight is about 1194 ft. per second.

(3) What would be the time of flight of a 9-in. shell, fired with a battering charge of pebble powder, over a range of 1000 yds.?

From example (1) we know that the remaining velocity at 1000 yds. = 1240 f.s.; so that the above question resolves itself to this:—In what *time* would the velocity of a 9-in. shell be reduced from 1420 to 1240 f.s.?

Here, $\textit{reduced time} = \frac{d^2}{w} t = \cdot 3183t.$

Now, corresponding to velocity 1240 in Table II. we find

	sec.
	1·5285
Do., do., velocity 1420	·8057
Subtracting,	·7228 = *reduced time.*

Hence, $\cdot 3183t = \cdot 7228,$

$\therefore\ t = 2\cdot 27 \text{ secs.}$

(4) In what *range* would the velocity of a 9-in. shell be reduced from 1420 to 1240 f.s.?

Here, $$\textit{reduced range} = \frac{d^2}{w}s = \cdot 3183s.$$

Now, corresponding to velocity 1240 in Table I. we find

	ft.
	2208·6
Do., do., velocity 1420,	1251·1
Subtracting,	957·5 = *reduced range.*

Hence, $$\cdot 3183s = 957\cdot 5 \text{ ft.},$$
$$\therefore\ s = 3000 \text{ ft., nearly.}$$

(5) The time of flight of a shell weighing 9 lbs., fired from the 9-pr. gun of 6 cwt., was observed to be 3·0 secs.; the muzzle velocity is known to be 1400 f.s. Find the striking velocity and the range.

Here, $$\textit{reduced time}\left(\frac{d^2}{w}t\right) = \cdot 9604 \times 3 = 2\cdot 8812 \text{ secs.}$$

(where $d = 2\cdot 94$ and $w = 9$).

Corresponding to velocity 1400 in Table II. we find

	secs.
	·8747
Adding *reduced time,*	2·8812
	3·7559

which corresponds to a velocity in the same table of 969 f.s., nearly.

Hence, striking velocity = 969 f.s.

Now to find range.

$$\textit{Reduced range}\left(\frac{d^2}{w}s\right) = \cdot 9604s.$$

Corresponding to velocity 969 in Table I. we find

	ft.
	4608·1
Do., do., velocity 1400,	1348·4
Subtracting,	3259·7 = *reduced range.*

Hence, $$\cdot 9604s = 3259\cdot 7 \text{ ft.},$$
$$\therefore\ s = \frac{3259\cdot 7}{\cdot 9604} = 3394 \text{ ft.}$$
$$= 1131\cdot 3 \text{ yds.}$$

Hence, range = 1131·3 yds.

(6) The range of the 16-pr. gun is observed to be 3139 ft. What is its striking velocity and time of flight; the muzzle velocity being 1358 f.s., weight of shell 16 lbs., diameter 3·54 ins.?

$$\frac{d^2}{w}s = \cdot 7832 \times 3139 \qquad \log \cdot 7832 = \bar{1}\cdot 8939$$

$$= 2458 \qquad \log 3139 = 3\cdot 4967$$

$$\log^{-1} 3\cdot 3906 = 2458$$

Corresponding to velocity 1358 f.s. in Table I.,

$$\begin{array}{r} 1558\cdot 4 \\ 2458\cdot 0 \\ \hline 4016\cdot 4 \end{array}$$

which corresponds to 1011 f.s. velocity on impact.

Again,

$$\frac{d^2}{w}t = \cdot 7832t.$$

Corresponding to velocity 1011 is 3·1653
Do., do., 1358 " 1·0272 (Table II.)
Subtracting, 2·1381

$$\therefore\ t = \frac{2\cdot 1381}{\cdot 7832} = 2\cdot 730 \text{ secs.} \qquad \begin{array}{rl} \log 2\cdot 1381 = & \cdot 3300 \\ \log \cdot 7832 = & \bar{1}\cdot 8939 \\ \hline \log^{-1} & \cdot 4361 = 2\cdot 730 \end{array}$$

$$\text{Max. height of trajectory} = \frac{gt^2}{8} = \frac{g\,(2\cdot 730)^2}{8} \qquad \begin{array}{rl} \log 2\cdot 730 = & \cdot 4362 \\ & 2 \\ \hline & \cdot 8724 \\ \log g = & 1\cdot 5077 \\ \hline & 2\cdot 3801 \\ \log 8 = & \cdot 9031 \\ \hline \log^{-1} & 1\cdot 4770 = 29\cdot 99 \end{array}$$

$$= 29\cdot 99 \text{ ft.}$$

Approximate Method of Finding Trajectories.

Find the trajectory of the Martini-Henry rifle at 500 yds. Weight of bullet = 480 grs., diameter of bore = ·45 in., muzzle velocity = 1353 f.s.

First, by Table I. the velocity can be found at every 100 ft.

Here, $$\frac{d^2}{w} = \frac{(\cdot 45)^2}{\cdot 06857} = 2\cdot 953,$$

$$\therefore \frac{d^2}{w} \times 100 = 295\cdot 3$$

Table I. for vel. 1353 =	1584		
	1879·3	= 1297 vel. at	ft. 100
	295·3		
	2174·6	= 1246 "	200
	295·3		
	2469·9	= 1198 "	300
	295·3		
	2765·2	= 1153 "	400
	295·3		
	3060·5	= 1113 "	500
	295·3		
	3355·8	= 1075 "	600
	295·3		
	3651·1	= 1043 "	700
	295·3		
	3946·4	= 1017 "	800
	295·3		
	4241·7	= 994 "	900
	295·3		
	4537·0	= 974 "	1000
	295·3		
	4832·3	= 955 "	1100
	295·3		
	5127·6	= 937 "	1200
	295·3		
	5422·9	= 920 "	1300
	295·3		
	5718·2	= 904 "	1400
	295·3		
	6013·5	= 889 "	1500

If it is required to find the height of the 500-yd. trajectory at intervals of 100 yds., it is only necessary to compute the time of flight over these intervals.

(1) To find time over 100 yds. range = 300 ft.

$$\frac{d^2}{w}t = 2{\cdot}953t = {\cdot}6955. \quad \text{Table II.}$$

$$\therefore\ t = \frac{{\cdot}6955}{2{\cdot}953} = {\cdot}2356 \text{ sec.}$$

for vel. 1198 = 1·7416
" 1353 = 1·0461
·6955

(2) Time over 200 yds.

$$2{\cdot}953t = 1{\cdot}4826$$

$$\therefore\ t = {\cdot}5021 \text{ sec.}$$

for vel. 1075 = 2·5287
" 1353 = 1·0461
1·4826

(3) Time over 300 yds.

$$2{\cdot}953t = 2{\cdot}3424$$

$$\therefore\ t = {\cdot}7934 \text{ sec.}$$

for vel. 994 = 3·3885
" 1353 = 1·0461
2·3424

(4) Time over 400 yds.

$$2{\cdot}953t = 3{\cdot}2592$$

$$\therefore\ t = 1{\cdot}104 \text{ sec.}$$

for vel. 937 = 4·3053
" 1353 = 1·0461
3·2592

(5) Time over 500 yds.

$$2{\cdot}953t = 4{\cdot}2301$$

$$\therefore\ t = 1{\cdot}432 \text{ sec.}$$

for vel. 889 = 5·2762
" 1353 = 1·0461
4·2301

These results may be thus expressed, for the sake of clearness :—

Distance.	Velocity.	Time.
yds.	f.s.	secs.
0	1353	·0000
100	1198	·2356
200	1075	·5021
300	994	·7934
400	937	1·1040
500	889	1·4320

When the time over a given range is known, the corresponding height of trajectory is given by the equation

$$y = \frac{gt}{2}(T - t);$$

where T is the whole time of flight, and t the time over given range,

Thus, at 100 yds. $t = \cdot 2356$.

$$y_{100} = \frac{g\,(\cdot 2356)}{2} \times 1\cdot 1964 = 4\cdot 537 \text{ ft.}$$

$$y_{200} = \frac{g}{2} \times \cdot 5021 \times \cdot 9299 = 7\cdot 515$$

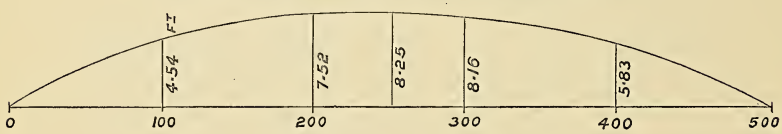
$$y_{300} = \frac{g}{2} \times \cdot 7934 \times \cdot 6386 = 8\cdot 155$$

$$y_{400} = \frac{g}{2} \times 1\cdot 1040 \times \cdot 3280 = 5\cdot 828$$

$$y_{500} = 0$$

Greatest height of trajectory $= \dfrac{g\,(1\cdot 4320)^2}{8} = 8\cdot 249$ ft.

TRAJECTORY OF MARTINI-HENRY RIFLE AT 500 YDS.



For low angles of elevation, trajectories computed on this principle are very approximately correct.

R.M. Academy,
October, 1875.

Table I.

A General Table of Values of $\frac{d^2}{w}\,s$ for Ogival-headed Shot.

V.	0	1	2	3	4	5	6	7	8	9
f.s.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
50	19604·0	19542·0	19480·2	19418·6	19357·2	19296·1	19235·2	19174·6	19114·3	19054·3
51	18994·6	18935·1	18875·8	18816·7	18757·8	18699·1	18640·7	18582·6	18524·6	18466·8
52	18409·2	18351·9	18294·9	18238·0	18181·3	18124·8	18068·5	18012·5	17956·7	17901·1
53	17845·7	17790·6	17735·6	17680·8	17626·2	17571·9	17517·8	17463·9	17410·1	17356·5
54	17303·2	17250·1	17197·2	17144·4	17091·8	17039·4	16987·1	16935·0	16883·1	16831·5
55	16780·2	16729·1	16678·1	16627·2	16576·5	16526·0	16475·7	16425·6	16375·6	16325·8
56	16276·2	16226·9	16177·7	16128·6	16079·6	16030·8	15982·2	15933·8	15885·6	15837·6
57	15789·8	15742·1	15694·6	15647·2	15600·0	15552·9	15506·0	15459·3	15412·7	15366·3
58	15320·1	15274·0	15228·1	15182·3	15136·7	15091·2	15045·9	15000·7	14955·7	14910·9
59	14866·2	14821·7	14777·3	14733·1	14689·0	14645·1	14601·3	14557·7	14514·2	14470·8
60	14427·7	14384·8	14341·9	14299·1	14256·4	14213·8	14171·3	14129·0	14086·9	14045·0
61	14003·3	13961·7	13920·2	13878·9	13837·6	13796·4	13755·3	13714·4	13673·7	13633·2
62	13592·8	13552·4	13512·2	13472·1	13432·2	13392·4	13352·7	13313·1	13273·7	13234·4
63	13195·2	13156·1	13117·3	13078·5	13039·8	13001·2	12962·8	12924·5	12886·3	12848·2
64	12810·2	12772·3	12734·6	12697·0	12695·5	12622·1	12584·8	12547·6	12510·6	12473·7
65	12436·9	12400·2	12363·7	12327·2	12290·8	12254·5	12218·3	12182·3	12146·4	12110·6
66	12074·9	12039·3	12003·9	11968·5	11933·2	11898·0	11863·0	11828·1	11793·2	11758·4
67	11723·7	11689·1	11654·7	11620·4	11586·2	11552·1	11518·1	11484·2	11450·4	11416·7
68	11383·0	11349·4	11316·0	11282·7	11249·5	11216·3	11183·3	11150·4	11117·5	11084·7
69	11052·0	11019·4	10987·0	10954·6	10922·3	10890·1	10857·9	10825·9	10794·0	10762·2
70	10730·5	10698·9	10667·4	10635·9	10604·5	10573·2	10542·0	10510·9	10479·9	10448·9
71	10418·0	10387·2	10356·5	10326·0	10295·5	10265·1	10234·8	10204·6	10174·4	10144·3
72	10114·3	10084·4	10054·6	10024·9	9995·2	9965·6	9936·1	9906·7	9877·4	9848·1
73	9818·9	9789·8	9760·8	9731·9	9703·0	9674·2	9645·5	9616·9	9588·3	9559·8
74	9531·4	9503·1	9474·9	9446·7	9418·6	9390·6	9362·6	9334·7	9306·9	9279·2
75	9251·6	9224·1	9196·6	9169·2	9141·8	9114·5	9087·3	9060·2	9033·1	9006·1
76	8979·2	8952·4	8925·7	8899·0	8872·3	8845·7	8819·2	8792·8	8766·4	8740·1
77	8713·9	8687·7	8661·6	8635·6	8609·7	8583·8	8558·0	8532·3	8506·0	8480·9
78	8455·3	8429·8	8404·4	8379·0	8353·7	8328·5	8303·3	8278·2	8253·2	8228·2
79	8203·3	8178·5	8153·7	8129·0	8104·3	8079·7	8055·2	8030·8	8006·4	7982·0
80	7957·7	7933·5	7909·3	7885·2	7861·1	7837·1	7813·2	7789·3	7765·5	7741·7
81	7718·0	7694·4	7670·8	7647·3	7623·8	7600·4	7577·0	7553·7	7530·5	7507·3
82	7484·2	7461·1	7438·1	7415·1	7392·2	7369·4	7346·6	7323·9	7301·2	7278·6
83	7256·0	7233·5	7211·1	7188·7	7166·3	7144·0	7121·8	7099·6	7077·5	7055·4
84	7033·4	7011·4	6989·5	6967·6	6945·8	6924·0	6902·2	6880·5	6858·9	6837·3
85	6815·8	6794·4	6773·0	6751·6	6730·3	6709·0	6687·8	6666·6	6645·5	6624·5
86	6603·5	6582·5	6561·6	6540·7	6519·9	6499·1	6478·4	6457·7	6437·1	6416·5
87	6395·9	6375·4	6355·0	6334·6	6314·2	6293·9	6273·7	6253·5	6233·3	6213·2
88	6193·1	6173·1	6153·1	6133·2	6113·3	6093·4	6073·6	6053·8	6034·1	6014·4
89	5994·8	5975·2	5955·7	5936·2	5916·7	5897·3	5877·9	5858·6	5839·3	5820·0
90	5800·8	5781·6	5762·5	5743·5	5724·5	5705·6	5686·7	5667·9	5649·2	5630·5
91	5611·8	5593·2	5574·7	5556·2	5537·7	5519·3	5500·9	5482·6	5464·4	5446·2
92	5428·1	5410·0	5392·0	5374·1	5356·2	5338·3	5320·5	5302·8	5285·1	5267·5
93	5249·9	5232·4	5215·0	5197·6	5180·2	5162·9	5145·7	5128·5	5111·4	5094·3
94	5077·3	5060·4	5043·5	5026·6	5009·8	4993·0	4976·3	4959·6	4943·0	4926·5
95	4910·0	4893·6	4877·3	4861·0	4844·7	4828·5	4812·4	4796·3	4780·3	4764·4
96	4748·5	4732·7	4716·9	4701·2	4685·5	4669·9	4654·4	4638·9	4623·5	4608·1
97	4592·8	4577·6	4562·4	4547·3	4532·2	4517·2	4502·3	4487·4	4472·6	4457·8
98	4443·1	4428·5	4413·9	4399·4	4384·9	4370·5	4356·2	4342·0	4327·8	4313·6
99	4299·5	4285·4	4271·4	4257·5	4243·7	4230·0	4216·4	4202·8	4189·3	4175·8
100	4162·4	4149·1	4135·9	4122·8	4109·7	4096·7	4083·8	4070·9	4058·1	4045·3

TABLE I.—(*Continued.*)

V.	0	1	2	3	4	5	6	7	8	9
f.s.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
101	4032·6	4020·0	4007·5	3995·0	3982·5	3970·1	3957·8	3945·6	3933·5	3921·4
102	3909·5	3897·7	3886·0	3874·3	3862·7	3851·2	3839·8	3828·5	3817·3	3806·1
103	3795·0	3784·0	3773·0	3762·1	3751·2	3740·4	3729·6	3718·9	3708·3	3697·7
104	3687·2	3676·8	3666·4	3656·1	3645·8	3635·6	3625·5	3615·5	3605·5	3595·6
105	3585·8	3576·1	3566·5	3556·9	3547·3	3537·8	3528·4	3519·1	3509·8	3500·6
106	3491·4	3482·3	3473·2	3464·2	3455·2	3446·3	3437·5	3428·7	3419·9	3411·1
107	3402·4	3393·8	3385·2	3376·7	3368·1	3359·6	3351·2	3342·8	3334·4	3326·0
108	3317·7	3309·5	3301·3	3293·1	3284·9	3276·7	3268·6	3260·5	3252·4	3244·3
109	3236·3	3228·4	3220·4	3212·5	3204·5	3196·6	3188·7	3180·9	3173·1	3165·3
110	3157·5	3149·7	3141·9	3134·2	3126·5	3118·7	3111·0	3103·3	3095·6	3087·9
111	3080·3	3072·8	3065·2	3057·6	3050·1	3042·5	3035·0	3027·5	3020·0	3012·6
112	3005·1	2997·7	2990·3	2982·9	2975·5	2968·1	2960·8	2953·4	2946·1	2938·7
113	2931·4	2924·1	2916·8	2909·6	2902·4	2895·2	2888·1	2880·9	2873·7	2866·6
114	2859·4	2852·3	2845·2	2838·1	2831·0	2823·9	2816·9	2809·8	2802·8	2795·8
115	2788·8	2781·8	2774·9	2767·9	2761·0	2754·0	2747·1	2740·2	2733·3	2726·5
116	2719·6	2712·8	2705·9	2699·1	2692·3	2685·5	2678·7	2672·0	2665·2	2658·5
117	2651·7	2645·0	2638·3	2631·6	2625·0	2618·3	2611·6	2605·0	2598·4	2591·8
118	2585·2	2578·6	2572·1	2565·5	2558·9	2552·4	2545·8	2539·3	2532·8	2526·3
119	2519·8	2513·4	2506·9	2500·4	2494·0	2487·5	2481·1	2474·7	2468·3	2461·9
120	2455·5	2449·1	2442·8	2436·4	2430·1	2423·8	2417·4	2411·1	2404·8	2398·5
121	2392·2	2386·0	2379·7	2373·5	2367·3	2361·0	2354·8	2348·6	2342·4	2336·2
122	2330·0	2323·9	2317·7	2311·6	2305·5	2299·3	2293·2	2287·1	2281·0	2274·9
123	2268·8	2262·7	2256·7	2250·7	2244·6	2238·6	2232·6	2226·6	2220·6	2214·6
124	2208·6	2202·6	2196·7	2190·7	2184·8	2178·8	2172·9	2166·9	2161·0	2155·1
125	2149·2	2143·3	2137·5	2131·6	2125·8	2119·9	2114·1	2108·2	2102·4	2096·6
126	2090·8	2085·0	2079·2	2073·4	2067·6	2061·9	2056·1	2050·4	2044·7	2038·9
127	2033·2	2027·5	2021·8	2016·1	2010·5	2004·8	1999·1	1993·5	1987·8	1982·2
128	1976·5	1970·8	1965·2	1959·6	1954·0	1948·4	1942·8	1937·2	1931·7	1926·1
129	1920·5	1915·0	1909·4	1903·9	1898·4	1892·8	1887·3	1881·8	1876·3	1870·8
130	1865·3	1859·8	1854·4	1848·9	1843·5	1838·0	1832·6	1827·2	1821·7	1816·3
131	1810·9	1805·5	1800·1	1794·7	1789·3	1783·9	1778·5	1773·1	1767·8	1762·4
132	1757·0	1751·7	1746·3	1741·0	1735·7	1730·4	1725·1	1719·8	1714·5	1709·2
133	1703·9	1698·6	1693·4	1688·1	1682·9	1677·6	1672·4	1667·1	1661·9	1656·7
134	1651·4	1646·2	1641·0	1635·8	1630·6	1625·4	1620·2	1615·0	1609·9	1604·7
135	1599·5	1594·4	1589·2	1584·1	1578·9	1573·8	1568·7	1563·5	1558·4	1553·3
136	1548·2	1543·1	1538·0	1533·0	1527·9	1522·8	1517·8	1512·7	1507·7	1502·6
137	1497·6	1492·5	1487·5	1482·5	1477·4	1472·4	1467·4	1462·3	1457·3	1452·3
138	1447·3	1442·3	1437·3	1432·4	1427·4	1422·4	1417·5	1412·5	1407·6	1402·6
139	1397·7	1392·7	1387·8	1382·9	1377·9	1373·0	1368·1	1363·1	1358·2	1353·3
140	1348·4	1343·5	1338·6	1333·7	1328·8	1323·9	1319·0	1314·1	1309·3	1304·4
141	1299·5	1294·7	1289·8	1284·9	1280·1	1275·2	1270·4	1265·6	1260·8	1255·9
142	1251·1	1246·3	1241·5	1236·6	1231·8	1227·0	1222·2	1217·4	1212·6	1207·8
143	1203·0	1198·2	1193·4	1188·7	1183·9	1179·1	1174·4	1169·6	1164·9	1160·2
144	1155·4	1150·7	1145·9	1141·2	1136·4	1131·7	1126·9	1122·2	1117·5	1112·7
145	1108·0	1103·3	1098·6	1093·9	1089·2	1084·5	1079·8	1075·1	1070·4	1065·8
146	1061·1	1056·4	1051·7	1047·1	1042·4	1037·7	1033·1	1028·4	1023·7	1019·1
147	1014·4	1009·8	1005·1	1000·5	995·8	991·2	986·6	981·9	977·3	972·7
148	968·0	963·4	958·8	954·1	949·5	944·9	940·3	935·7	931·1	926·5
149	921·9	917·3	912·7	908·1	903·5	898·9	894·3	889·7	885·1	880·6
150	876·0	871·4	866·9	862·3	857·8	853·2	848·6	844·1	839·5	835·0
151	830·4	825·9	821·3	816·8	812·2	807·7	803·2	798·6	794·1	789·5
152	785·0	780·5	775·9	771·4	766·9	762·3	757·8	753·3	748·7	744·2
153	739·7	735·2	730·7	726·2	721·7	717·2	712·7	708·2	703·7	699·2
154	694·7	690·2	685·7	681·2	676·8	672·3	667·8	663·3	658·8	654·4

TABLE I.—(*Continued.*)

V.	0	1	2	3	4	5	6	7	8	9
f.s.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
155	649·9	645·4	640·9	636·5	632·0	627·5	623·1	618·6	614·2	609·7
156	605·3	600·8	596·4	591·9	587·5	583·0	578·6	574·1	569·7	565·2
157	560·8	556·4	551·9	547·5	543·0	538·6	534·2	529·7	525·3	520·9
158	516·4	512·0	507·6	503·1	498·7	494·3	489·9	485·5	481·1	476·7
159	472·3	467·9	463·5	459·1	454·7	450·3	445·9	441·5	437·1	432·7
160	428·3	423·9	419·5	415·1	410·7	406·4	402·0	397·6	393·2	388·9
161	384·5	380·1	375·8	371·4	367·1	362·7	358·3	354·0	349·6	345·3
162	340·9	336·5	332·2	327·8	323·5	319·1	314·8	310·4	306·1	301·7
163	297·4	293·1	288·7	284·4	280·0	275·7	271·4	267·0	262·7	258·4
164	254·0	249·7	245·4	241·0	236·7	232·4	228·1	223·8	219·5	215·2
165	210·9	206·6	202·3	198·0	193·7	189·4	185·1	180·8	176·5	172·3
166	168·0	163·7	159·5	155·2	150·9	146·7	142·4	138·2	134·0	129·7
167	125·5	121·3	117·0	112·8	108·6	104·3	100·1	95·9	91·7	87·5
168	83·3	79·1	74·9	70·7	66·5	62·3	58·1	53·9	49·8	45·6
169	41·4	37·2	33·1	28·9	24·8	20·7	16·5	12·3	8·2	4·1
170	0·0									

Table II.

A General Table of Values of $\frac{d^2}{w}\,t$ for Ogival-headed Shot.

V.	0	1	2	3	4	5	6	7	8	9
f.s.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.
50	26·5083	26·3844	26·2612	26·1388	26·0172	25·8963	25·7762	25·6567	25·5379	25·4198
51	25·3024	25·1857	25·0697	24·9543	24·8396	24·7255	24·6121	24·4994	24·3873	24·2759
52	24·1652	24·0552	23·9457	23·8368	23·7285	23·6209	23·5139	23·4075	23·3017	23·1965
53	23·0919	22·9879	22·8845	22·7817	22·6795	22·5778	22·4766	22·3760	22·2760	22·1766
54	22·0778	21·9795	21·8817	21·7844	21·6877	21·5915	21·4958	21·4006	21·3060	21·2119
55	21·1184	21·0254	20·9328	20·8407	20·7491	20·6580	20·5674	20·4773	20·3877	20·2986
56	20·2100	20·1218	20·0341	19·9468	19·8600	19·7737	19·6879	19·6025	19·5175	19·4330
57	19·3489	19·2653	19·1821	19·0994	19·0171	18·9352	18·8537	18·7726	18·6920	18·6118
58	18·5320	18·4527	18·3738	18·2952	18·2170	18·1392	18·0619	17·9849	17·9083	17·8321
59	17·7563	17·6809	17·6059	17·5312	17·4569	17·3830	17·3094	17·2362	17·1634	17·0910
60	17·0190	16·9474	16·8761	16·8051	16·7344	17·6640	16·5940	16·5244	16·4551	16·3862
61	16·3176	16·2494	16·1815	16·1139	16·0466	15·9797	15·9131	15·8468	15·7809	15·7153
62	15·6500	15·5851	15·5204	15·4560	15·3919	15·3281	15·2646	15·2014	15·1386	15·0761
63	15·0139	14·9520	14·8903	14·8289	14·7678	14·7070	14·6465	14·5863	14·5264	14·4668
64	14·4074	14·3483	14·2895	14·2309	14·1726	14·1146	14·0569	13·9994	13·9422	13·8853
65	13·8286	13·7722	13·7160	13·6601	13·6045	13·5491	13·4940	13·4391	13·3845	13·3301
66	13·2759	13·2220	13·1684	13·1150	13·0618	13·0089	12·9562	12·9038	12·8516	12·7996
67	12·7479	12·6964	12·6451	12·5940	12·5432	12·4926	12·4422	12·3920	12·3421	12·2924
68	12·2429	12·1937	12·1447	12·0958	12·0471	11·9986	11·9504	11·9025	11·8547	11·8071
69	11·7597	11·7125	11·6655	11·6188	11·5723	11·5260	11·4799	11·4340	11·3882	11·3426
70	11·2972	11·2520	11·2070	11·1622	11·1176	11·0732	11·0290	10·9850	10·9412	10·8975
71	10·8540	10·8107	10·7675	10·7246	10·6819	10·6394	10·5970	10·5548	10·5127	10·4708
72	10·4291	10·3875	10·3461	10·3049	10·2639	10·2232	10·1826	10·1421	10·1018	10·0616
73	10·0216	9·9816	9·9420	9·9025	9·8632	9·8241	9·7851	9·7462	9·7075	9·6689
74	9·6305	9·5922	9·5541	9·5162	9·4784	9·4408	9·4034	9·3661	9·3289	9·2919
75	9·2550	9·2183	9·1817	9·1453	9·1090	9·0728	9·0368	9·0009	8·9652	8·9296
76	8·8941	8·8588	8·8236	8·7886	8·7537	8·7189	8·6843	8·6498	8·6155	8·5813
77	8·5472	8·5133	8·4795	8·4458	8·4122	8·3788	8·3455	8·3123	8·2793	8·2464
78	8·2136	8·1809	8·1484	8·1160	8·0837	8·0515	8·0195	7·9876	7·9558	7·9241
79	7·8926	7·8612	7·8299	7·7987	7·7676	7·7366	7·7058	7·6751	7·6445	7·6139
80	7·5835	7·5532	7·5231	7·4931	7·4631	7·4333	7·4036	7·3741	7·3446	7·3152
81	7·2859	7·2567	7·2276	7·1986	7·1698	7·1411	7·1125	7·0840	7·0556	7·0272
82	6·9990	6·9709	6·9429	6·9150	6·8871	6·8594	6·8318	6·8043	6·7769	6·7496
83	6·7224	6·6953	6·6683	6·6414	6·6146	6·5878	6·5612	6·5347	6·5083	6·4819
84	6·4557	6·4296	6·4036	6·3776	6·3517	6·3259	6·3002	6·2746	6·2491	6·2236
85	6·1983	6·1731	6·1480	6·1229	6·0979	6·0730	6·0482	6·0236	5·9990	5·9744
86	5·9499	5·9255	5·9012	5·8770	5·8529	5·8289	5·8049	5·7810	5·7572	5·7335
87	5·7099	5·6864	5·6629	5·6395	5·6162	5·5930	5·5699	5·5468	5·5238	5·5009
88	5·4781	5·4553	5·4326	5·4100	5·3875	5·3651	5·3428	5·3205	5·2983	5·2762
89	5·2541	5·2321	5·2102	5·1884	5·1666	5·1449	5·1233	5·1018	5·0803	5·0589
90	5·0375	5·0163	4·9952	4·9741	4·9531	4·9321	4·9112	4·8904	4·8697	4·8491
91	4·8286	4·8082	4·7878	4·7675	4·7473	4·7272	4·7072	4·6873	4·6674	4·6476
92	4·6279	4·6083	4·5888	4·5693	4·5499	4·5306	4·5114	4·4923	4·4732	4·4542
93	4·4353	4·4165	4·3978	4·3791	4·3605	4·3421	4·3236	4·3053	4·2870	4·2688
94	4·2506	4·2326	4·2147	4·1968	4·1790	4·1612	4·1436	4·1260	4·1085	4·0911
95	4·0738	4·0565	4·0393	4·0222	4·0052	3·9883	3·9714	3·9546	3·9379	3·9213
96	3·9047	3·8882	3·8718	3·8555	3·8393	3·8231	3·8070	3·7910	3·7751	3·7592
97	3·7434	3·7277	3·7121	3·6966	3·6811	3·6657	3·6504	3·6352	3·6200	3·6049
98	3·5899	3·5750	3·5602	3·5455	3·5308	3·5162	3·5017	3·4873	3·4729	3·4586
99	3·4444	3·4303	3·4163	3·4024	3·3885	3·3747	3·3610	3·3474	3·3339	3·3204
100	3·3070	3·2937	3·2805	3·2674	3·2544	3·2414	3·2285	3·2157	3·2030	3·1904

TABLE II.—(*Continued.*)

V.	0	1	2	3	4	5	6	7	8	9
f.s.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.
101	3·1778	3·1653	3·1529	3·1406	3·1284	3·1163	3·1042	3·0922	3·0803	3·0685
102	3·0567	3·0451	3·0335	3·0220	3·0106	2·9992	2·9879	2·9767	2·9656	2·9546
103	2·9436	2·9328	2·9220	2·9113	2·9007	2·8902	2·8798	2·8694	2·8591	2·8489
104	2·8388	2·8288	2·8188	2·8089	2·7991	2·7894	2·7798	2·7703	2·7608	2·7514
105	2·7420	2·7328	2·7236	2·7144	2·7053	2·6963	2·6874	2·6785	2·6697	2·6610
106	2·6523	2·6437	2·6351	2·6266	2·6182	2·6098	2·6015	2·5932	2·5850	2·5768
107	2·5687	2·5606	2·5526	2·5446	2·5366	2·5287	2·5208	2·5130	2·5052	2·4975
108	2·4898	2·4821	2·4745	2·4669	2·4593	2·4518	2·4443	2·4369	2·4295	2·4221
109	2·4147	2·4074	2·4001	2·3928	2·3855	2·3783	2·3711	2·3640	2·3568	2·3497
110	2·3426	2·3355	2·3285	2·3214	2·3144	2·3074	2·3005	2·2936	2·2867	2·2798
111	2·2729	2·2661	2·2592	2·2524	2·2456	2·2388	2·2321	2·2254	2·2187	2·2120
112	2·2053	2·1987	2·1921	2·1855	2·1789	2·1723	2·1658	2·1593	2·1528	2·1464
113	2·1399	2·1335	2·1271	2·1207	2·1134	2·1079	2·1016	2·0953	2·0890	2·0827
114	2·0764	2·0702	2·0639	2·0577	2·0515	2·0453	2·0392	2·0330	2·0269	2·0208
115	2·0147	2·0087	2·0026	1·9966	1·9905	1·9845	1·9785	1·9726	1·9667	1·9607
116	1·9548	1·9489	1·9431	1·9372	1·9314	1·9255	1·9197	1·9139	1·9081	1·9024
117	1·8966	1·8909	1·8852	1·8795	1·8738	1·8681	1·8625	1·8568	1·8512	1·8455
118	1·8399	1·8343	1·8287	1·8232	1·8176	1·8121	1·8066	1·8011	1·7956	1·7901
119	1·7847	1·7792	1·7738	1·7684	1·7630	1·7576	1·7523	1·7469	1·7416	1·7362
120	1·7309	1·7256	1·7203	1·7150	1·7098	1·7045	1·6992	1·6940	1·6888	1·6836
121	1·6784	1·6732	1·6681	1·6629	1·6578	1·6526	1·6475	1·6424	1·6373	1·6323
122	1·6272	1·6222	1·6172	1·6121	1·6071	1·6021	1·5971	1·5922	1·5872	1·5823
123	1·5773	1·5724	1·5675	1·5626	1·5577	1·5528	1·5479	1·5431	1·5382	1·5334
124	1·5285	1·5237	1·5189	1·5141	1·5093	1·5045	1·4997	1·4950	1·4903	1·4855
125	1·4808	1·4761	1·4714	1·4667	1·4620	1·4574	1·4527	1·4481	1·4435	1·4388
126	1·4342	1·4296	1·4250	1·4204	1·4158	1·4113	1·4068	1·4022	1·3977	1·3932
127	1·3887	1·3842	1·3797	1·3752	1·3708	1·3663	1·3619	1·3574	1·3530	1·3486
128	1·3442	1·3398	1·3354	1·3310	1·3267	1·3223	1·3180	1·3137	1·3093	1·3050
129	1·3007	1·2964	1·2921	1·2878	1·2835	1·2792	1·2749	1·2707	1·2665	1·2622
130	1·2580	1·2538	1·2496	1·2454	1·2412	1·2370	1·2329	1·2287	1·2246	1·2204
131	1·2163	1·2122	1·2080	1·2039	1·1998	1·1957	1·1916	1·1876	1·1835	1·1794
132	1·1754	1·1713	1·1673	1·1633	1·1592	1·1552	1·1512	1·1472	1·1432	1·1393
133	1·1353	1·1313	1·1274	1·1234	1·1195	1·1156	1·1116	1·1077	1·1038	1·0999
134	1·0960	1·0922	1·0883	1·0844	1·0806	1·0767	1·0729	1·0690	1·0652	1·0614
135	1·0575	1·0537	1·0499	1·0461	1·0423	1·0385	1·0347	1·0309	1·0272	1·0234
136	1·0196	1·0159	1·0121	1·0084	1·0047	1·0009	·9972	·9935	·9898	·9861
137	·9824	·9787	·9751	·9714	·9678	·9641	·9605	·9568	·9532	·9496
138	·9459	·9423	·9387	·9351	·9315	·9279	·9243	·9207	·9172	·9136
139	·9100	·9065	·9029	·8994	·8959	·8923	·8888	·8853	·8818	·8782
140	·8747	·8712	·8677	·8642	·8607	·8572	·8538	·8503	·8468	·8434
141	·8399	·8364	·8330	·8296	·8261	·8227	·8193	·8159	·8125	·8091
142	·8057	·8023	·7989	·7956	·7922	·7888	·7854	·7821	·7787	·7754
143	·7720	·7687	·7654	·7620	·7587	·7554	·7521	·7488	·7454	·7421
144	·7388	·7355	·7322	·7289	·7256	·7223	·7191	·7158	·7125	·7093
145	·7060	·7028	·6996	·6963	·6931	·6899	·6867	·6834	·6802	·6770
146	·6738	·6706	·6674	·6642	·6610	·6578	·6546	·6514	·6483	·6451
147	·6419	·6387	·6356	·6324	·6293	·6261	·6230	·6198	·6167	·6136
148	·6104	·6073	·6042	·6011	·5980	·5949	·5918	·5887	·5856	·5825
149	·5794	·5763	·5732	·5701	·5671	·5640	·5609	·5579	·5548	·5518
150	·5487	·5457	·5426	·5396	·5366	·5335	·5305	·5275	·5244	·5214
151	·5184	·5154	·5124	·5094	·5064	·5034	·5004	·4974	·4944	·4914
152	·4884	·4854	·4824	·4795	·4765	·4735	·4705	·4676	·4646	·4617
153	·4587	·4558	·4528	·4499	·4470	·4440	·4411	·4382	·4353	·4323
154	·4294	·4265	·4236	·4207	·4178	·4149	·4120	·4091	·4062	·4033

TABLE II.—(*Continued.*)

V.	0	1	2	3	4	5	6	7	8	9
f.s.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.
155	·4004	·3975	·3946	·3918	·3889	·3860	·3831	·3803	·3774	·3745
156	·3717	·3688	·3660	·3632	·3603	·3575	·3547	·3518	·3490	·3462
157	·3433	·3405	·3377	·3349	·3320	·3292	·3264	·3236	·3207	·3179
158	·3151	·3123	·3095	·3067	·3039	·3012	·2984	·2956	·2928	·2901
159	·2873	·2845	·2818	·2790	·2763	·2735	·2707	·2680	·2652	·2625
160	·2597	·2570	·2542	·2515	·2488	·2460	·2433	·2406	·2378	·2351
161	·2324	·2297	·2270	·2243	·2216	·2189	·2162	·2135	·2108	·2081
162	·2054	·2027	·2000	·1973	·1947	·1920	·1893	·1866	·1839	·1813
163	·1786	·1759	·1733	·1706	·1680	·1653	·1627	·1600	·1574	·1548
164	·1521	·1495	·1469	·1442	·1416	·1390	·1364	·1338	·1311	·1285
165	·1259	·1233	·1207	·1181	·1155	·1129	·1103	·1077	·1051	·1026
166	·1000	·0974	·0949	·0923	·0897	·0872	·0846	·0821	·0795	·0770
167	·0745	·0720	·0695	·0669	·0644	·0619	·0594	·0569	·0543	·0518
168	·0493	·0468	·0443	·0418	·0393	·0368	·0343	·0318	·0294	·0269
169	·0244	·0220	·0195	·0171	·0146	·0122	·0098	·0073	·0049	·0024
170	·0000									

TABLE OF THE DIMENSIONS, WEIGHT, AND TONNAGE OF CARRIAGES, &c., IN USE WITH AN ARMY CORPS.

(*Shewing the aggregate weight of every vehicle with its ordinary load, and that of the component parts; the tonnage required for transport in vessels or boats, when standing in the smallest space,* without the wheels being removed; *and the tonnage required for* shipment, *without load*).

COMMUNICATED BY

COLONEL G. T. FIELD, R.A.,

SUPERINTENDENT ROYAL CARRIAGE DEPARTMENT.

Description.	Weight. Component parts.	Weight. Total.	For transport in boats. Exterior dimensions. Length.	Width.	Height.	Tonnage.	Tonnage for shipment without load.	Remarks.
	cwt. qr. lb.	cwt. qr. lb.	ft.in.	ft.in.	ft.in.	tons.	tons.	
Carriages, iron, wrought, travelling, R.M.L., complete, field. — 16-pr. — Gun and carriage	25 3 12	42 0 2	13 9¾	6 3½	5 1	11·04	4·112	
Limber	16 0 18							
9-pr. 8cwt. — Gun and carriage	20 1 5	35 3 17	13 2	6 3½	5 1	10·53	3·818	
Limber	15 2 12							
9-pr. 6cwt. — Gun and carriage	17 2 0	33 0 12	13 5¼	6 3½	5 1	10·74	3·818	
Limber	15 2 12							
Spare. 16-pr. — Carriage	12 3 6	24 0 6	12 2	6 3½	5 1	9·73	4·112	
Limber	11 1 0							
Spare. 9-pr. 8 cwt. — Carriage	11 1 5	22 0 27	"	"	"	"	3·818	
Limber	10 3 22							
Spare. 9-pr. 6 cwt. — Carriage	10 3 12	21 3 6	"	"	"	"	"	
Limber	10 3 22							
Wagons, complete. Iron, wrought. Amn. R.M.L. with spare wheel. 16-pr. — Wagon	24 3 22	41 0 3	15 0	6 3½	5 3¾	12·53	4·438	
Limber	16 0 9							
9-pr. 8 or 6 cwt. — Wagon	24 0 26	40 0 2	"	"	"	"	4·373	
Limber	15 3 4							
R.A. Forge — Wagon	30 1 0	44 3 21	12 6	6 3¾	7 5	14·63	5·500	
Limber	14 2 21							
R.A. Store — Wagon	28 2 0	42 1 14	12 1½	6 3¾	7 5	14·19		
Limber	13 3 14							
R.A. Amn. and store. 16-pr.	—	47 1 24	10 8	6 3	7 2	11·94	4·137	Lock under.
9-pr.	—	46 1 10						
Rocket, 9-pr.	—	37 0 18						
S.A. ammunition	—	48 3 11*						
Cart, ammn., S.A., regl. reserve	—	20 2 3*	12 0½	6 3½	5 5	10·26	2·468	
Carts, complete — General service	—	23 2 18	12 6	6 1½	6 0	11·48	2·079	Estimated approximate load, 15 cwt.
Water	—	7 0 7	11 9¼	6 0	6 4	11·18	4·075	Weight, *with* water, 16¾ cwt.

* If for Snider rifles, deduct from wagon 2 cwt. 3 qrs. 9 lbs.; cart, 1 cwt. 18 lbs.

(*Continued.*)

Description.	Weight.		For transport in boats.				Tonnage for shipment, without load.	Remarks.
	Components parts.	Total.	Exterior dimensions.			Tonnage.		
			Length.	Width.	Height.			
	cwt. qr. lb.	cwt. qr. lb.	ft. in.	ft. in.	ft. in.	tons.	tons.	
Oven, travelling, steam	—	42 2 21	12 0	6 2¾	8 2½	15·34	10·711	
Wagons, complete. With springs. Ambulance	—	20 1 0	11 8	6 3	9 1	16·55	3·625	*Lock under;* load 2cwt., men not included.
Wagons, complete. With springs. Bakery	—	43 2 0	12 1½	"	8 4	15·78	8·604	Estimated approximate load 16½ cwt.
Wagons, complete. Bread and meat. Bread	—	48 1 0	"	"	"	"	"	Estimated approximate load 18½ cwt.
Wagons, complete. Bread and meat. Meat or butchery	—	56 2 11	"	"	8 3½	15·71	"	Estimated approximate load 30 cwt.
Wagons, complete. General service.. Forge	—	33 0 16	10 7	6 7	7 8	13·35	4·516	*Lock under;* load 15½ cwt.
Wagons, complete. General service.. Store	—	47 0 14					4·304	*Lock under;* estimated approximate load 30 cwt.
Wagons, complete. Pontoon. Wagon, with superstructure, anchor, &c.	27 3 12	37 1 12	21 4	6 0¼	7 9	27·98	7·502	
Wagons, complete. Pontoon. Boat, with saddle, oars, &c.	9 2 0						9·615	
Wagons, complete. Forge, R.E.	—	36 1 17	10 10½	6 1¼	8 6½	14·17	4·615	High sides; approximate load 15 cwt.
Wagons, complete. General service, R.E. / Miners'	—	51 0 14	"	"	8 6¼	14·14	4·408	High sides; estimated approximate load 30 cwt.
Wagons, complete. Office, telegraph	—	28 2 6	11 4	"	9 0¾	15·67	11·962	With spare wheel, approximate load 5 cwt.
Wagons, complete. Lithographic	—	29 3 0	"	"	9 0½	15·64	"	Approximate load 6½ cwt.
Wagons, complete. Photographic	—	30 3 0	"	"	"	"	"	Approximate load 7½ cwt.
Wagons, complete. Printing	—	33 0 0	"	"	9 0¼	15·60	"	Approximate load 9¾ cwt.
Wagons, complete. Trestle	—	27 3 12	18 5	6 9¼	4 10½	15·19	7·502	
Wagons, complete. Wire, telegraph	—	34 3 0	12 10½	6 1¼	6 3½	12·36	6·777	Approximate load 13½ cwt.

Royal Carriage Department,
Royal Arsenal,
September 1, 1875.

NEW GARRISON CARRIAGES.

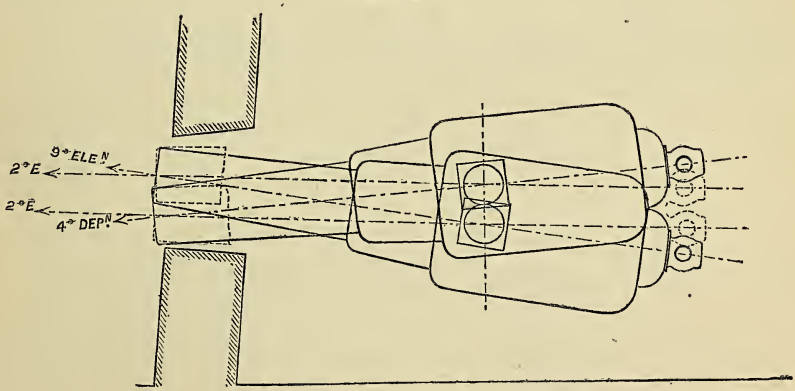
BY

MAJOR W. KEMMIS, R.A.

10-in. M.L.R. Muzzle-Pivoting Carriage and Platform.

Before proceeding to describe the carriage, it may be well to mention that the term "muzzle-pivoting" is applied to this carriage because a gun mounted upon it is capable, as it were, of pivoting in a vertical plane about a point at its muzzle. The object of this is to enable the gun to be fired at considerable elevation or depression through a port of small height, which otherwise the size of the latter would render impossible; and it is attained by supplying means in the carriage of altering the height of the trunnions. The advantage gained may readily be seen by reference to Fig. I., which shows the trunnions at

Fig. I.



two different levels, with the elevation or depression which can be obtained at each. In this figure it may be noticed that the chase, at maximum elevation, is some little distance clear of the edge of the port. This is to allow for its clearing the latter in recoil, as—due to the slope of the platform—it then rises.

I.—*The Carriage.*

(Weight, complete, 120 cwt.; tonnage, 4·995 tons.)

The carriage is of "double-plate" construction, the frames of the brackets being of wrought-iron. The latter are formed each with a slot or recess in it, for the trunnion-bearing to slide in, the inner bracket-plate being cut away over the slot and the outer strengthened. The trunnion-bearing is a solid block of wrought-iron, without metal lining, in which the trunnion is held by a capsquare with two double-nutted bolts.

The brackets are secured in the usual manner upon a bottom plate, and connected by three low transoms. The former has a slot cut in it to receive a hydraulic lift, which, acting under the trunnion-coil of the gun, raises or lowers the latter to any level required. The lift is immediately supported by two strengthening plates, riveted one on each side of the slot, and secured by four small movable plates and two clips.

The hydraulic arrangement* consists of a cylinder, *A* (Fig. II.), and ram, *B*, of wrought-iron, with a reservoir, *C*, of cast-iron, which contains the pump, *D*, of metal. The ram has a cradle, *b*, which, when the lift is in action, bears against a patch on the gun. The pump is double-acting, as follows:—Its plunger, *d*, is worked by the camb, *e*, and cross shaft, *f*—the latter passing through the brackets of the carriage and having a lever upon each end. When the plunger is raised, water (mixed with methylated spirit) is drawn in at the inlet valve *g*, while the water already above it is forced by the passages *h* and *i* to the ram, its pressure at the same time keeping the outlet valve, *k*, closed. When the plunger is lowered, the pressure on the water under it closes the inlet valve, opens the outlet valve, and sends a flow by the passage, *i*, to the ram, and also by *h* to the space above the piston. Thus in both up and down stroke, pressure is transmitted to the ram, and work is done in raising the gun. In order to lower the latter, it is only necessary to permit the water to flow back to the reservoir from the cylinder, through the passage, *m*, provided for the purpose, by unscrewing the lowering plug, *L*; this is done by pushing a lever attached to the crank, *l*, and passing out through the left bracket of the carriage. *N* and *O* are plugs which close respectively the filling and emptying hole of the reservoir.

The hydraulic lift is supplemented by a screw lift, upon which the gun is intended to rest when fired, and not upon the former.† It

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* This lifting arrangement, designed and made in the Royal Carriage Department, is deserving of special attention, for its compactness and the readiness with which it can be removed, as a whole, from the carriage, or any part be got at for repair without removal. In other such lifts—for example, those used in the navy—the ram and pump are separate and connected by tubes; the connections being parts of weakness, while the tubes themselves necessitate an increased expenditure of labor.

† There is nothing in the hydraulic lift itself to forbid the gun being fired resting upon it, and upon two occasions this has been done; but the carriage is not constructed to take the strain of discharge upon the bottom plate, to which it would then be transmitted from the ram.

In naval muzzle-pivoting carriages movable blocks are used instead of screws, to support the

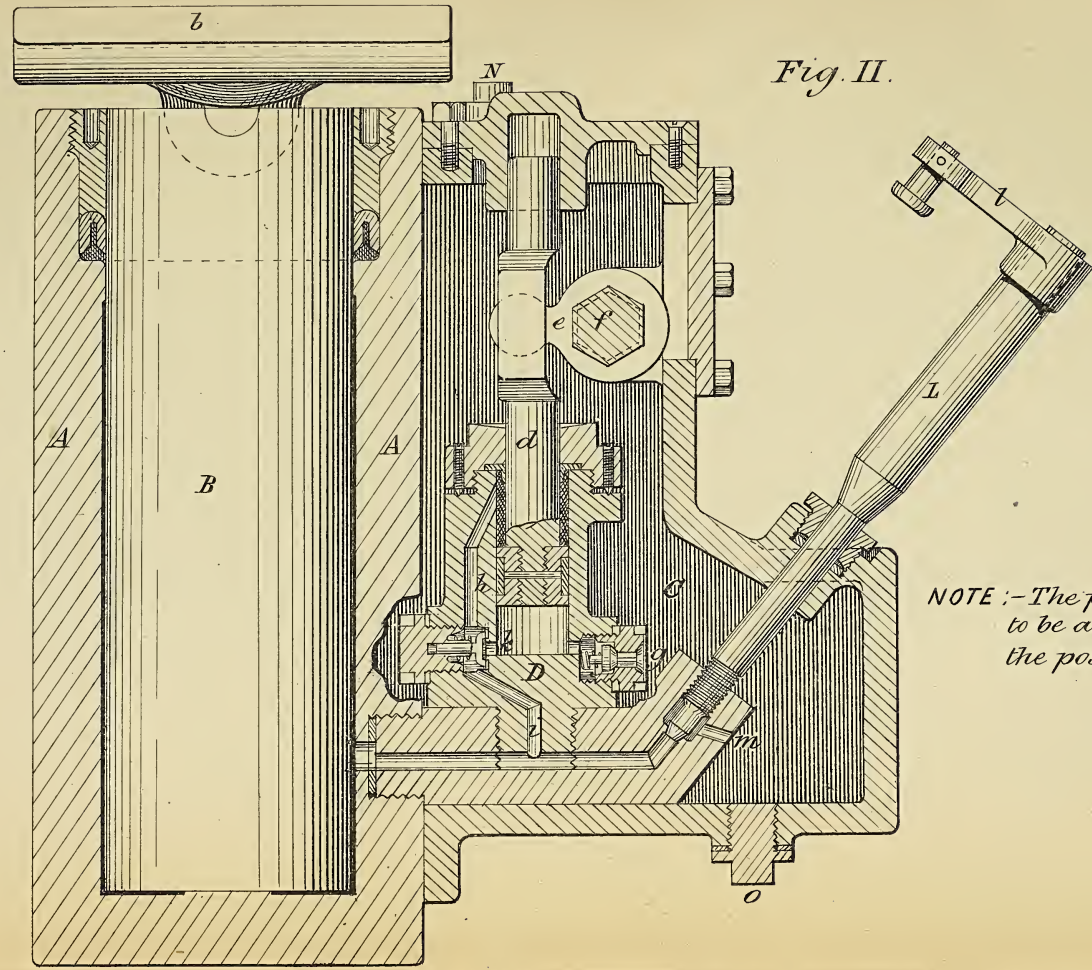

Fig. II.

NOTE :- The pump is adjusted to be at right angles to the position shewn.

consists of a strong screw under each trunnion-block, resting in a bearing in the bracket of the carriage and passing through a nut by which it is moved, the latter having a large bevel wheel formed on it, into which a pinion, upon the front of a shaft lying longitudinally inside the bracket, gears. The longitudinal shafts are driven through a suitable train of wheels by one of two cross shafts, with winch handles, at the rear of the carriage. The front cross shaft is used when the screw lift is required to raise the gun; the rear—which drives at greater speed than the front—when the screws are merely following up the hydraulic lift.*

The height of the axis of the gun in the lowest position is 4 ft. 5½ ins., when from 2° to 9° of elevation can be obtained; in the highest position 5 ft. 5½ ins., when from 4° of depression to 2° of elevation can be given. A marker is attached to the left trunnion-block, to show what elevation or depression can be given at any particular height.

Elevating gear, of the worm-wheel pattern, is fitted on both sides of the carriage, the elevating bar being straight and attached to the gun by a link, to accomodate any alterations of level of the trunnions.

The carriage has the usual rollers and minor fittings.

II.—*The Platform.*

(Weight, 102 cwt.; tonnage, 5·510 tons.)

The platform is the same, in general construction, as the first pattern 10-in. casemate platform, but higher—taking 13-in. trucks in front and rear—and is fitted with the same traversing and running-back gear.

The hydraulic lift of the carriage being central, necessitates the use of two hydraulic buffers on the platform—one at each side. They are of the service pattern, with 1·08-in. holes in the piston.

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gun when fired; these are of two different heights, giving with the bottom of the trunnion slots three different levels. Over this plan, screws may be said to possess two advantages—namely, "instead of three particular levels, any desired level may be obtained with them," and "the level can be arranged at extreme traverse of the platform," (the screws being worked at the rear of the carriage, while a man must pass to the side to place the block.) This second advantage seems but of small consequence; for if necessary to alter the level, it is easy to traverse the platform a little to give the required room. The first advantage, if of any moment (and it is evidently not so considered for sea service), becomes very doubtful when the complication and cost at which it is obtained are considered. The screw lift, no doubt, is alternative, in case of failure of the hydraulic; but if not necessary for other reasons, common lifting jacks might possibly furnish a simpler. In M.P. carriages for 38-ton guns, about to be made, it is proposed to use screws merely for following up and for firing upon, giving them a quick speed but not sufficient power for lifting; also, instead of one central hydraulic lift, to use two movable jacks, standing each on a base attached to the carriage bracket outside, and acting against a stud on the end of the trunnion of the gun. The advantage of using two independent instead of one single jack is, however, questionable, on account of the difficulty of working them uniformly; and the use of two jacks has for some time been abandoned in naval M.P. carriages.

* The hydraulic lift is much more rapid, as well as easier to work than the screws. For example, four men on the pump lever can, without relief, raise the gun from the lowest to the highest position in 1 min. 40 secs.; while eight men, with relief, cannot do the same with the screws under 12 minutes. Again, in lowering from the highest to the lowest position with the hydraulic lift, one man pushes the lever handle and the gun sinks in 5 secs.; while with the screws, if the weight of the gun rest upon them, it takes about the same time as lifting—viz., 12 minutes—and if the weight be not on them, between 1 and 2 minutes.

12·5-in. M.L.R. of 38 tons, Carriage and Casemate Platform.

I.—*The Carriage.*

This carriage is of "double-plate" construction, upon Capt. Scott's principle—namely, with low brackets, the frames of which are of cast-iron, and a well between them.

The brackets are supported by three transoms, and each is further strengthened by a knee-stay. The transoms and stays extend below the brackets, to form the well of the carriage, which is completed by a bottom plate riveted beneath. The latter does not extend to the rear transom, in order to give access there to the interior of the carriage for placing skidding when the gun is being mounted or dismounted.

The eccentric axles of the rear rollers are worked, as in naval heavy carriages, by a hydraulic jack,* with an alternative arrangement of lever and tackle. The jack is placed upon the left of the carriage, inside the bracket, attached to a bearing upon the latter, its ram being keyed to a crank upon the shaft; the lever upon the same side of the carriage, outside the bracket, keyed upon the end of the shaft. The extremity of the lever is formed into a treble block, a corresponding quadruple one being attached to the side of the carriage. To bring the near rollers into action the lever is pulled down, and when they are not in use it is secured by a pawl.

The elevating gear is similar to that of the "Devastation" turret carriage, and consists of an arc, secured to the gun, top and bottom, on the right side, worked by a metal hand-wheel outside the bracket of the carriage, through a train of wheels and pinions. Attached to a bearing upon the bracket is a clamping arrangement, consisting of a bow or cramp, two friction-pieces, and an adjusting screw with lever handle. Tightening the screw presses the friction-pieces against the elevating arc, and clamps it. The gain of power in elevating is 58·3 : 1.

To attach the carriage to the endless chains of the running-back (or up) gear of the platform, it is fitted with nipping gear (Scott's). This consists of a sprocket plate (or plate with projecting teeth) on each side (one for each chain), connected by a short cross shaft inside the well of the carriage, which plates are lowered, when it is desired that their teeth may catch in the chains, by means of a link and eccentric, worked by a lever outside the carriage on the left. The chains pass through brackets beneath the carriage which hold them up to the sprocket plates when the latter are forced down. A counter-weight is attached to their cross shaft, to keep the sprocket plates up and clear of the chains when not in use.

The carriage is fitted with the usual holding-down clips, buffer bracket, &c.

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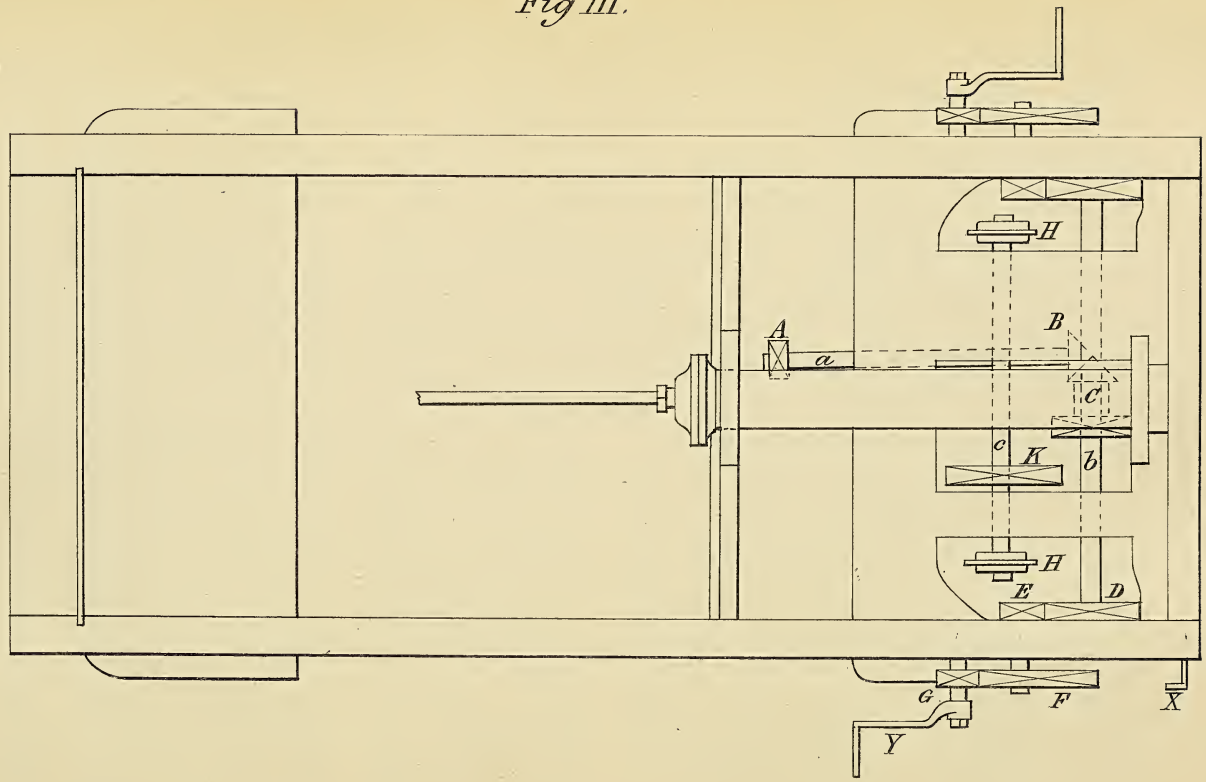
* This jack is "Tangye's double-action to 10 tons." The action of the pump is precisely as described for that of the lift in the 10-in. muzzle-pivoting carriage.

Fig III.



II.—*The Platform.*

(Allowing a recoil of 6 ft.)*

The platform is similar in general construction to that for the 12-in. M.L.R. gun of 25 tons.

The sides are 15½ ft. long and 24 ins. in greatest depth. They are connected by four transoms, two bottom plates, and two truck plates.

The trucks (13 ins. in diameter in front and 18 ins. in rear), are secured on their axles, each by a collar and pin. They are placed 10 ft. apart, and set to radii of 10 ft. 2 ins. and 20 ft. 2 ins. The front trucks are of steel.

The front bottom plate is slotted, to give access to the nuts between the first and second transoms.

The front truck plate is set down, to clear the buffer bracket of the carriage; the second transom being extended down to meet it.

The hydraulic buffer is special; its piston-rod 3 ins. in diameter. It is secured on the platform in the usual manner.

The platform is fitted with rack traversing and chain (Scott's) running-back gear, worked by the same winch handles, similar to that already in use in the navy.

The traversing gear is as follows:—A short longitudinal shaft (*a*, Fig. III.) is placed under the rear of the platform, having a bevel metal pinion, *A*, upon its front, and another, *B*, upon its rear extremity. The former gears into a cast-iron horizontal rack fixed upon the floor of the casemate, and the latter into the bevel part of a metal clutch double pinion, *C*, carried upon a cross shaft, *b*, under the platform. The shaft has upon each extremity, inside the side of the platform, a spur wheel, *D*, into which a pinion, *E*, carried upon a spindle passing through the side, gears. The spindle has upon its outer extremity a spur wheel, *F*, which is driven by a pinion, *G*, with winch handle, *Y*. The gain of power in traversing is 44·15 : 1.

The running-back gear consists of two endless chains, one on either side of the platform, inside, passing over sprocket wheels, *H*, *H*, the front wheel secured in an adjusting fork, by which the tension of the chain can be regulated, and the rear fixed on a cross shaft, *c*, lying a little to the front of the cross shaft of the traversing gear. This shaft has a spur wheel, *K*, upon it, into which the spur portion of the clutch double pinion of the traversing arrangement gears, the bevel portion being thrown out of gear with the pinion of the traversing shaft. The clutch is moved, as desired, to work either the traversing or running-back gear, by a lever handle, *X*, at the left rear of the platform, which is secured by a keep pin. The gain of power for running back is 86·5 : 1.

Proposed Experimental Fittings of the Platform for the 38-ton Gun.

It is proposed to fit, experimentally, a casemate platform as follows:—

1. The trucks to be 4½ ins. instead of 3 ins. wide on the sole, in

* Platforms allowing a recoil of 7 ft. are also to be made.

order to give them better bearing on the racers and prevent the latter being dented on discharge. The racers (steel) to be without flanges, $4\frac{1}{2}$ ins. in thickness, and simply bedded in concrete; the front racer in one piece, the rear in two.

2. To modify the hydraulic buffer, on an ingenious plan proposed by Mr. Butter (Manager R.C.D.), in order to prevent the shock on discharge to the platform and its fittings from the sudden check to recoil. The modification consists in replacing the ordinary four holes in the piston by a semicircular groove at each side of it—the latter fitting over a rib secured along the interior of the buffer cylinder. The clearance between the grooves and ribs furnishes the passage for the return flow of the oil on discharge, and this clearance is made variable —large at first, so that there may be comparatively little opposition to recoil, and gradually decreasing after, that the opposition may increase—by making the ribs tapering. An adjusting arrangement is also added by which the amount of clearance or area of passage can be varied with the charge (or probable violence of recoil), consisting of sliding pieces placed in the piston head, which by means of a wedge can be pushed out to reduce, or drawn in to increase, the area. The wedge is moved as required by a graduated screw in the top of the piston, to get at which it is necessary to bring the latter under the filling hole of the buffer.

3. To fit the carriage and platform with a "compressor stop," in order to hold the carriage after recoil, and prevent its running up of itself. The stop to be formed by two compressor bars under the carriage, which on recoil enter and jam between corresponding plates on the platform; the latter being set to give the required amount of compression, or relieved, by a lever handle at the side of the platform.

4. To fit the platform with "chain loading" gear (designed in R.C.D.), consisting of a pitch chain, formed to bend in one direction only, which serves as rammer or sponge stave, the required head being keyed to it. The chain lies in an iron trough under the centre of the platform, from which it is led to the muzzle by an iron standard attached to the breast of the platform; the standard being made telescopic in two parts, so that the upper portion may be moved clear when the gun is run out. The chain is worked by a sprocket wheel, which is driven through suitable wheels and pinions, to gain the necessary power, by winch handles at the sides of the platform.

5. To fit the platform for traversing by external power.* (1) By "steam," the power being conveyed to the platform by shafting; (2) by "hydraulic power," conveyed through tubing: in each case the power to be applied to the existing traversing and running-back gear of the platform, also to work the chain-loading gear and further bollards, placed one on each side of the platform, for the loading tackle.

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* In a casemate platform, the pivot being imaginary and lying much to the front, it is difficult to transmit motion from any fixed point in the casemate to any fixed point in the platform; the distance varying in length and direction with the angle of traverse of the latter.

In (1) a telescopic shaft, with bevel wheel at each end, placed beneath the floor of the casemate, will receive the motion from a fixed shaft from the engine, through the intervention of a vertical pivot (also under the floor) with bevel wheel, and communicate it to a short vertical shaft projecting downwards from the platform towards the front, which, as the latter is traversed, moves along a slot cut in the floor. From the vertical shaft the motion is conveyed to the gear of the platform by a shaft within the latter. The shaft conveying the power to the platform being telescopic and working round a fixed pivot, allows of its adapting itself to the motion of the platform when traversed, though that motion is about a point in the embrasure.

In (2) a flexible tube will convey the pressure from a fixed tube under the floor of the casemate, communicating with the accumulator, to a Brotherhood engine* attached to the rear of the platform. This engine, by the pressure communicated to it, will directly drive a short shaft, which will convey the motion to the gear of the platform. A second flexible tube will carry off the waste water from the engine.

In both (1) and (2) suitable clutches will be provided, so that all or any particular portion of the platform gear may be instantaneously disconnected from the primary power; while, as already mentioned, each part can be worked by hand.

December, 1875.

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* The Brotherhood engine is a patent three-cylinder engine for producing motion directly from steam or water pressure.

THE 80-TON GUN.

BY

MAJOR E. MAITLAND, R.A.,

ASSISTANT SUPERINTENDENT ROYAL GUN FACTORIES.

THE contest carried on for so many years between guns and armour-plates, between attack and defence, entered on a new phase in the latter half of 1873. Up to that period the guns had so far succeeded in getting the better of their tough antagonists, that many, even of our foremost engineers and shipbuilders, began to talk of the advisability of giving up the application of iron plates to ships altogether, and to advocate the building of rapidly-moving vessels, unfitted to withstand the attack of heavy shell, but furnished with torpedoes and perhaps rams. The Russians, however, were hard at work on a ship of tremendous power—the "Peter the Great"—which was to carry a very powerful armament, and to be protected by 20 ins. of iron. The Italians were moving in the same direction, and the Germans were laying the foundation of an iron-clad navy, constructed with all the latest improvements. It was certain that we possessed no guns which could pierce 20 ins. of iron, under the most favourable circumstances; and if it proved to be practicable to set afloat efficient vessels defended by such a mass of metal, there could be no doubt that the ships were getting the better of the artillery.

The Admiralty, at this juncture, proposed a design for a new turret-ship to carry four guns capable of piercing 20 ins. of iron, firmly backed, at 1000 yds.; and H.M.S. "Inflexible," now in a forward state at Portsmouth, and the 80-ton guns—of which she will carry four—are the results of this proposal.

The armour-piercing capability of guns is a question involved in much obscurity. A very great number of rounds has been fired at Shoeburyness against targets constructed to represent the sides of iron-clads, but no entirely satisfactory data have been established. Major W. H. Noble has put forward an empirical formula which appears to give fairly approximate results when the guns are not very large and the plates not very thick, and Lieut. English, R.E., has published some highly intricate calculations of the work required to be done by the shot in penetrating armour. These calculations possess great ingenuity, but can scarcely be said, at present, to rest on any but a theoretical basis. The same may be said of the methods in use on the Continent, where no experiments at all equal in importance or extent to ours have been carried out.

Thus, when the Director of Naval Ordnance applied to the War Office in 1873 for a design for a gun which should penetrate 20 ins. of iron, strongly backed, at 1000 yds., he propounded a problem whose solution could only be approximately estimated; and the consequence was that opinions were extremely conflicting.

Ultimately, it was decided that the gun should weigh about 80 tons,

and that the bore should be 16 ins. If the proportions hitherto found best in smaller ordnance could be adhered to in this huge weapon, the calibre of 16 ins. would be suited by a projectile weighing 1650 lbs., propelled by a charge of somewhere about 300 lbs. of powder. It was anticipated that a muzzle velocity of not less than 1400 f.s. could be realised without giving rise to undue strain on the material.

The experience gained by the Committee on Explosives in their experiments with other guns—notably, with the 38-ton gun—enabled them to speak with some certainty as to the ballistic capabilities of the new piece of ordnance proposed. The large-grained slowly-burning powder recently introduced was adapted to give high velocity in large calibres, with but low maximum pressures in the bore, provided the gun was long enough to permit the shot to realise the benefit of a slow-burning explosive. Turret-ships had hitherto possessed the inconvenience of requiring the guns to be so short that, when drawn back by the recoil, the muzzle should be a considerable distance within the port-hole. This was necessary in order that the men might load the gun inside the turret; and it need scarcely be said that this defect was regarded by the advocates of breech-loading systems as one of the highest importance—as, indeed, it was. Fortunately, at this juncture, a plan of loading outside the turret by hydraulic machinery was put forward by the well-known firm of Sir W. G. Armstrong & Co. (It is understood that Mr. G. Rendel is the member of the firm specially connected with the proposal.)

It would be beyond the scope of this paper to enter minutely into the details of the elaborate arrangement by which the ammunition, machinery, and men are all placed in perfect security under the deck outside the turret; it will be enough to explain that directly the guns are fired at the object the turret is rapidly revolved till they come to the loading position; that meanwhile the muzzles have been depressed, and appear, through a hole in the wall of the turret underneath the deck, opposite the hydraulic rammers, which first sponge out the bores, deluging them with water by a special contrivance, and then force home the cartridge and projectile, which have at that moment been raised to the muzzles by another portion of the machinery. This excellent arrangement has been fitted to one of the turrets of the "Thunderer," armed with 38-ton guns, and has proved, so far, exceedingly efficient. Practice makes perfect, even with big guns and hydraulics; and at the trial which was lately carried out, the time between successive pairs of rounds was soon brought as low as 2 min. 33 secs. I say *pairs of rounds*, because both the guns in the turret can be loaded simultaneously, and would usually be fired simultaneously. When it is reflected that this was the first attempt, and that it included traversing the turret round for some distance, and, indeed, all the conditions of actual warfare that can be obtained during peace, it will, I think, be admitted to promise a great success.

It is intended to fit a similar contrivance to the "Inflexible," the only important difference being that the guns will be depressed without being withdrawn from the port-hole, so that the chase of the piece while protruding from the turret will reach to a protected situation, at the loading position, under the deck. It appears that by the adoption

of this method greater speed and safety will be attained for muzzle-loaders than has hitherto been achieved for breech-loaders similarly situated; since the great weight of the breech-closing apparatus necessitates special appliances, in addition to those employed for putting in the shot and cartridge. Length of bore thus no longer offers any difficulty, and the automatically attached gas-checks, which are expanded by the pressure of the charge to completely seal the windage, are found to be, if anything, more satisfactory than the lead coating or copper rings of breech-loading shell; so that, without specially advocating either system, it certainly seems to me that some of the most powerful arguments for a change in the construction of the English heavy guns are now turned the other way.

Since, then, the question of length offered no difficulty, it was decided to make the bore of the 80-ton gun 24 ft.—or, in gunners' parlance, 18 calibres—long, the calibre being fixed at 16 ins. A special arrangement was devised for putting a strong screw, carrying a shackle, into the cascable, so that the gun could be readily lifted, and when in its place could be shortened by the removal of the screw. By this means the length of the portion of the gun behind the bottom of the bore was reduced to 33 ins., only one inch more than in the far smaller 38-ton guns; the amount saved being, of course, a clear gain inside a turret or casemate. The diameter of the breech is 6 ft.

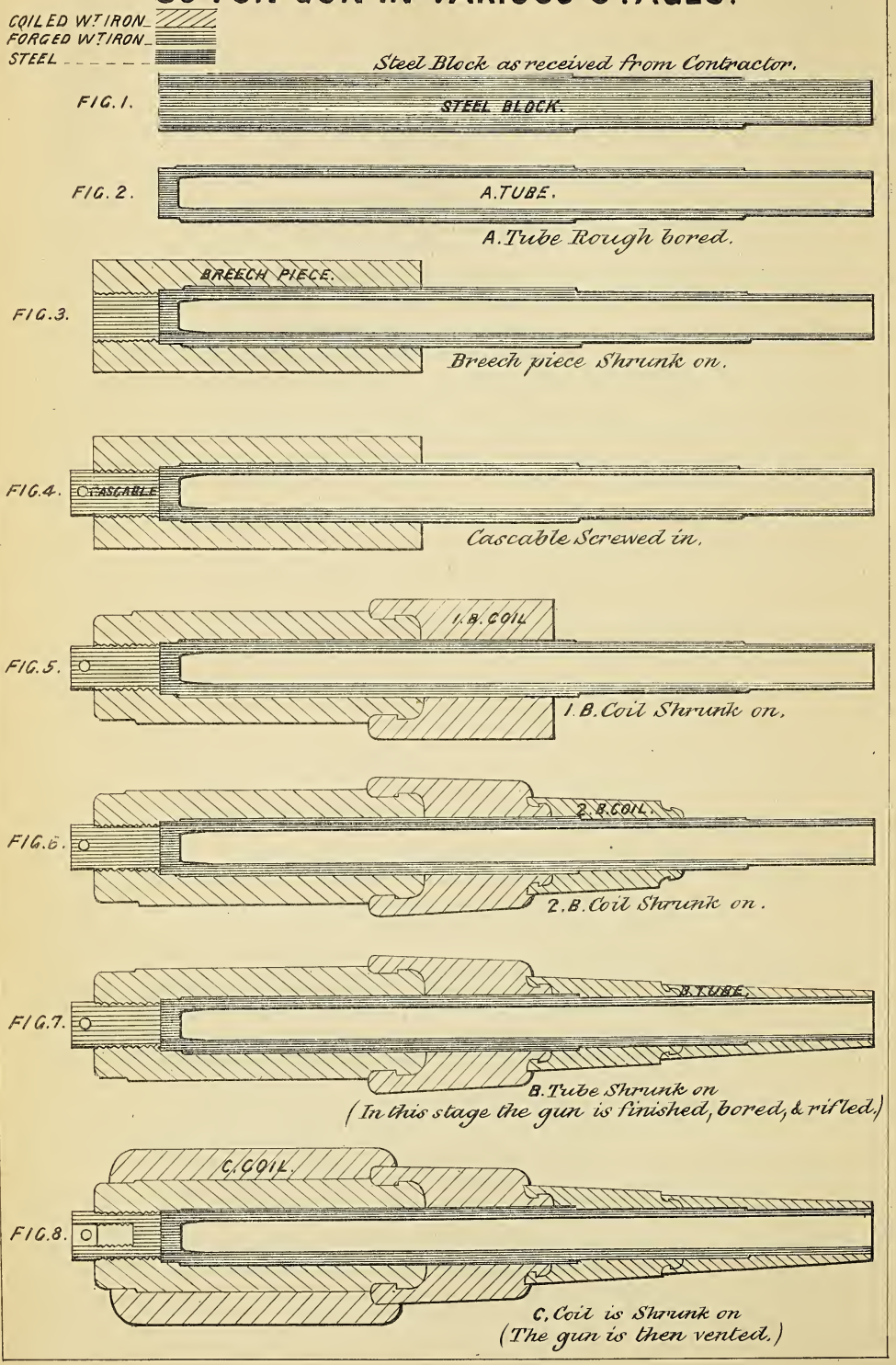
With our constitutional notions, matters of this magnitude move but slowly; and eager spirits sometimes pine for an intelligent despotism, if only they could first catch the intelligent despot. It was not till March, 1874, that authority was given for the construction of the 80-ton gun.

The preparation of this vast piece of ordnance—weighing more than twice as much as any previously made for service—may be divided into two parts; one being the actual making of the gun, the other the enlargement of lathes, the raising of roofs, the strengthening of cranes, bridges, and railways, with many other alterations which will readily suggest themselves. Besides these important points, there remain to be taken into account the projectiles and the carriage, while the powder question requires further consideration and experiment.

It will be best to begin with the gun itself. Those familiar with the heavy ordnance of our service will have noticed that of late years the thin coils and many-stepped outline belonging to the ·lier models of the Armstrong system have gradually given place to the bolder curves and massive coils of what is known as the "Fraser" construction. The change has resulted in greater strength, endurance, and economy; and, as will be seen later on, these qualities, as far as yet tested, have been amply realised in the 80-ton gun.

The interior of the gun is formed by a solid-ended steel tube, procured from Messrs. Firth, of Sheffield. The manufacture of these tubes is, to a certain extent, a speciality. Without entering into the various controversies always going on regarding steel, it may certainly be affirmed that no other firm in England has succeeded, up to the present time, in turning out the magnificent steel blocks required for our manufacture. That for the 80-ton gun weighed 16½ tons, and no flaws can be detected in it. The material used is entirely that known

80 TON GUN IN VARIOUS STAGES.



as crucible steel, being melted in about 240 small crucibles, whose contents are run into a large mould. The process is very expensive and eminently unscientific—having, indeed, nothing to recommend it but its success. This quality has, however, undoubtedly been attained by Messrs. Firth.

It is not requisite for me to describe minutely the details of the manufacture of our ordnance; I will merely indicate the successive processes of building up the 80-ton gun. Over the rear end of the steel tube is shrunk a very powerful coil, called the breech-piece. This is made of a single bar, 12 ins. thick from inside to outside, hammered, rolled, and coiled—forming a cardinal point in the mode of construction. The cascable is next screwed in, so as to abut firmly against the solid end of the tube, and the *B* coils are then shrunk on into their places. The ponderous *C* coil, carrying the trunnions, comes last, and is in truth a marvellous piece of forging. It was made of two coils—one outside the other—and was 18 ins. thick. These coils were welded together under the 40-ton hammer. It should be stated that, in order to obtain greater certainty of soundness and ease of manipulation, both the breech-piece and the *C* coil were made in two pieces, which were welded together, end to end; care being taken that the weld of the breech-piece was not inconveniently near that of the *C* coil.

The sketch appended gives a clear idea of the successive processes, and the Table A shows the weights of the forgings, both in the rough and after finishing. It will be noticed that the total amount of iron used is twice that of the gun. This waste is due to the necessity for turning off the surfaces and ends of the coils, so as to obtain a fine clear metal, free from flaws. The metal turned off is, of course, used again.

TABLE A.

Detail of Weight of Material for 80-*ton M.L.R. Gun.*

Name of piece.	Size of bars.	Length of bars.	Weight of bars.	Weight of iron used in gun.	Finished weight of parts of gun.
			tons. cwt. qrs.	tons. cwt. qrs.	tons. cwt. qrs.
A tube (steel) ...	... ...	..	...	16 10 0	7 13 0
Breech piece ...	12 × 10 × 8½	50	7 10 0	29 8 0	17 10 0
	11 × 10 × 8½	150	21 18 0		
Cascable	... ...	...	...	1 7 0	0 19 0
1 *B* coil	8½ × 6½ × 5¾	86	6 9 0	27 6 0	13 8 0
	"	86	6 9 0		
	"	192	14 8 0		
2 *B* coil	8½ × 6½ × 5¾	30	2 5 0	6 5 0	4 3 0
	7½ × 6½ × 5½	32	2 4 0		
	7 × 6 × 5	31	1 16 0		
B tube	7½ × 6 × 5¾	60	4 2 2	8 1 1	3 8 0
	7 × 6 × 5	40	2 6 2		
	6 × 4½ × 4½	40	1 12 1		
Trunnion	... ...	...	...	18 0 0	...
C coil	8½ × 6½ × 5¾	173	12 19 2	57 19 0	34 5 0
	8½ × 6½ × 5¾	173	12 19 2		
	9½ × 8½ × 7	300	32 0 0		
				164 16 1	81 6 0

The now well-known principle of shrinking on the successive layers affords very great additional strength to the system, since by its aid the strain of the discharge is transmitted to the very exterior of the gun, which thus adds its quota to the resistance. The efficacy of the shrinking process is well shown by the measurements taken of the interior of the gun during manufacture. Thus the shrinkage of the powerful coiled breech-piece caused the bore to contract ·020 in., and the compression of the massive outer coil carrying the trunnions was so great that it was transmitted through the breech-piece, and caused a further contraction of ·023 in. in the bore.

The shrinkage was so adjusted that the maximum contraction (·043 in.) took place at a point 32 ins. from the end of the bore, and gradually died away in each direction towards breech and muzzle. Thus the pressure of the gas—which is greatest in the powder-chamber and for a short distance in front of the base of the shot—was directly transmitted to the outer or *C* coil, the great strength and thickness of which form an important point in the system. It often happens, on firing a new gun, that the shock of discharge permits the atoms of the material to shake themselves, as it were, and to settle down more comfortably. This sometimes results in the shrinkage of the outer coils taking increased effect on the steel tube; but more usually the steel tube fits its exterior better to the interior of the coils, or perhaps slightly compresses their nearest particles, so that a small expansion ensues. Before enumerating and describing the experiments made with the 80-ton gun, it will be convenient to finish this part of the subject, and to draw attention to the table (B) of measurements here given. The figures represent the diameter of the bore at short

TABLE B.

Showing Horizontal Measurements of the Bore of the 80-*ton Gun.*

Inches from muzzle.	Before shrinking on outer coil.	After shrinking on outer coil.	After firing 21 rounds.	
	ins.	ins.	ins.	ins.
190	14·498	14·498	14·498	
196	14·498	14·498	14·498	Contraction.
202	14·498	14·495	14·494	·001
208	14·498	14·494	14·493	·001
214	14·499	14·495	14·494	·001
220	14·499	14·494	14·492	·002
226	14·499	14·490	14·490	Nil.
				Expansion.
232	14·500	14·488	14·489	·001
238	14·500	14·482	14·484	·002
244	14·499	14·480	14·481	·001
250	14·499	14·476	14·480	·004
256	14·499	14·476	14·478	·002
262	14·500	14·480	14·481	·001
268	14·500	14·483	14·484	·001
274	14·495	14·481	14·481	Nil.

NOTE.—The vertical measurements are almost identical with those given above.

intervals, taken horizontally, before and after the shrinking on of the outer or *C* coil. To the compression given must be added that of the

breech-piece, which was put on before the interior of the tube was "finish-bored." This compression reached its maximum of ·02 in. at from 240 ins. to 270 ins. from the muzzle. The gun, after firing 21 rounds, exhibited, as shown by the table, a slight contraction in front of 226 ins. from the muzzle, and a slight expansion in rear of this point, both being so small that the bore may be said to be practically unaltered; and thus the outer coils retain undiminished their power of promptly taking up the strain imposed on the tube.

It may here be remarked that the object of the tube is not so much to afford transverse strength as to furnish a good and impenetrable surface. In fact, the Woolwich guns are constructed to stand with safety, even if the tube should split.

It will be observed that I have hitherto omitted all reference to the relation between the expected strain of the discharge and the thickness of the various layers of metal composing the gun. The fact is that no really trustworthy data exist for accurate calculations on this point. The time during which the maximum pressure is exerted is exceedingly small, and the rate at which the strain is taken up by the coils is altogether unknown, while experiments on masses of size sufficient to give practical results would be enormously expensive. Rough calculations do exist, but I confess that I do not put much faith in any of them; believing that, as a plain matter of fact, the real limit to the power that can be got out of a gun of the present construction, when suitable powders and shot are employed, lies in the recoil. I mean that we can increase the charge and weight of projectile of our guns, boring them up if required, till no carriages can be made to stand the shock, and that therefore a certain weight is necessary. It is obvious that, in anything so risky as a gun, such weight as must be carried should be so disposed as to strengthen the piece to the utmost, even though some additional expense should be thereby incurred. Ordinary prudence demands this, and hence I do not consider the possession of a true theory of the relation between strain and dimensions to be *at present* of very great practical importance, though I fully admit its interest from a scientific point of view.

It was thought desirable, in order to obtain as much information as possible, to bore the 80-ton gun to 14½ ins. in the first instance, and to increase the calibre by half-an-inch at a time till the full size of 16 ins. should be reached. It is anticipated that, by carrying on experiments at each stage, much valuable knowledge relating to the behaviour of powder and the manufacture of heavy projectiles will be acquired.

The gun was ready, in its 14½-in. calibre, for firing early in Sept. 1875, having taken just eighteen months to complete. Of this time, several months were occupied by the necessity for enlarging various parts of the plant in the Royal Gun Factories. The unprecedented size of the bars forming the coils entailed much heavy forge work, and the rolling mill then in use was not powerful enough to turn out such sections of iron; the coiling furnace required alteration; the roof of the tempering house, where the steel tube is toughened in oil, had to be raised; the hydraulic crane had to be patched up to take weights beyond its safe strength; a lathe and boring machine of immense

length were obvious necessities; the railways, wherever the gun was intended to travel, required strengthening; the bridge over the canal was almost reconstructed; while the additions to the Proof Butt "made Ossa like a wart."

The carriage deserves special mention. It was designed to suit the new method of firing heavy guns recently introduced at the Royal Gun Factories, by which the travelling sleigh forms also the firing carriage, and on the discharge of the gun recoils along the rails up a slope arranged so as to gradually check the speed, and to enable the gun to run up again of itself to the firing place, where it is stopped by powerful breaks. The body of the carriage consists of two vast cheeks, composed chiefly of wrought-iron, and fastened together by strong transoms. The trunnions rest on a box containing layers of india-rubber, below and behind, to act as buffers. Two bogies, each having six wheels (the centre ones without flanges), support this massive framework. Vertical wrought-iron pins, 9 ins. in diameter, act as pivots on which the carriage turns in going round curves, and indeed form its sole attachment to the bogies. Over the axles are more buffers, consisting, as before, of plates of india-rubber, which material is also employed for the same purpose in the driving buffers. The whole mass, including bogies, weighs 40 tons; so that when the gun is mounted the rails have to support a load of 120 tons, distributed over a length of 14½ ft. Considerable experience had been already gained by the Royal Carriage Department in the construction of these running proof sleighs as used for guns of from 12 to 38 tons; and it may be at once stated that the new carriage, as far as the trials have at present gone, has proved very successful, having sustained the shock of firing without any material damage whatever.

The motion of the ponderous mass up the slope after firing is marvellously steady, and indeed graceful. The apparent docility of by far the most powerful piece of ordnance in the world impresses the beholder with the idea that it cannot be so very deadly after all; but an inspection of the sandbank at the Butt, where the projectile has cut its way in and tossed the resisting heap to the right and left, speedily dispels the illusion.

When the gun is mounted on its carriage and pointed at the velocity screens in front of the Proof Butt, the muzzle is about 7 ft. from the ground; a derrick is therefore required to raise the cartridge and projectile for loading. This derrick is fixed on a light travelling stage, which runs on the rails, and which conveys the shot from the pile to the gun. The gear of the derrick enables one man to raise a ton. The cartridges required to feed so large a piece look something like sacks of coal, and their great weight and length rendered it necessary to provide a bronze cradle on wheels, which should run over a bridge out of the window of the filling room into the ammunition cart. The cradle is then conveyed to the travelling loading stage, on to which it runs out under the derrick.

All the projectiles fired into the Butt are cylinders of cast-iron, studded in the usual manner to suit the rifling. In the case of the 80-ton gun in its 14½-in. calibre each cylinder weighed 1260 lbs.,

inclusive of the gas-check. This important adjunct consists of a stout copper ring, flanged round the rim, and is applied at the base of the projectile, so that the pressure of the gas drives the flanged rim out against the surface of the bore, sealing the windage completely. These gas-checks were secured to the shot by a strong screw in the middle—a method of fastening which will probably be superseded by a more convenient automatic attachment.

In the centre of the screw fastening on the gas-check is placed a crusher-gauge, to register the maximum pressure of the gas on the base of the shot. There is fortunately no occasion for me to describe the scientific instruments used to determine pressures and velocities, since a paper on these subjects is being prepared for the present issue by one specially qualified for the task (Capt. C. Jones, R.A.); and therefore I merely refer those unacquainted with the details of the apparatus to his explanations. As previously mentioned, on firing a built-up gun for the first time, a slight re-adjustment of the parts sometimes takes place; and hence it is always desirable to fire a few rounds before piercing the sides for the insertion of crusher-gauges. It is found by experience that the highest pressure in a gun is usually encountered at the centre of the bottom of the bore; and it therefore is advantageous to possess the means of ascertaining the amount of this pressure, even with guns not pierced for gauges. This object has been attained by the use of a copper cup, which fits the end of the bore, and which carries, screwed into its base, a crusher-gauge, projecting into the end of the cartridge. This gauge gives fairly accurate results, though it is not so trustworthy as those of the usual form. It is liable to be jarred and shaken by the discharge, and thus errors are occasioned—which, however, lie almost invariably in the direction of excess, and therefore on the side of safety.

The 80-ton gun, when ready for firing in its 14½-in. calibre, was mounted on its carriage by the hydraulic crane in the Royal Gun Factories, and was drawn to the Butt by two locomotives—one being that in use in the Department, and the other a slightly more powerful one, borrowed from the South-Eastern Railway Company; and no great difficulty was experienced in getting it to the firing position on the rails at the foot of the recoil slope. The first experiment consisted in firing—to prove the gun—six rounds of increasing charges of the powder which had proved suitable to the 38-ton guns, and had been adopted for them. Although no holes, except that for the vent, were yet pierced in the sides of the piece, still, by means of the gauges in the cup at the bottom of the bore and in the base of the shot, sufficient information was obtained to warrant the gradual enlargement of the charges from 170 lbs. to 240 lbs., and the surprising velocity of 1550 f.s. was realised without exposing the gun to any very inordinate strain. On the successful termination of the proof rounds, the gun was taken back to the factory, examined, and found entirely uninjured. It was then pierced with holes in its axis and sides to take seven crusher-gauges, and sent back to the Butt.

Table C. (compiled by Capt. Jones) gives full details of all the rounds fired up to the present time from the gun, and I will make a few remarks on the form into which Capt. Jones has thrown the

TABLE C.

Experiments with 80-*ton R.M.L. Gun, Expl: No.* 405, *Calibre* 14·5 *ins.*

WORK REALISED. *November and December*, 1875.

1	2	3	4	5		6	7	8	9	10	11	12	13	14	15	16
				Velocity.				Energy.					Energy.			
								Total.					Total.		Per inch of shot's circumference.	
No. of round.	Powder.	Charge.	Projectile.	Muzzle.	At 1000 yds.	Maximum pressure.	Mean pressure on powder-chamber. (A, 1, 2, and 3 gauges.)	Theoretic.	Realised.	Per pound of powder.	Per ton of mean pressure on powder-chamber.	Factor of effect.	At the muzzle.	At 1000 yds.	At the muzzle.	At 1000 yds.
		lbs.	lbs.	ft.	ft.	tons.	tons.	ft. tons.	ft. tons.	ft. tons	ft. tons.		ft. tons.	ft. tons.	ft. tons.	ft. tons.
1	1·5-in., 22. 3. 75.*	170	1259	1394	1298	23·0 at A.†	—	18,224	16,946	99·7	—†	92·8	16,946	14,704	371	323
2	"	190	1259	1425	1325	21·2 " A.†	—	19,728	17,708	93·2	—†	89·7	17,708	15,323	388	336
3	"	210	1259	1474	1370	23·6 " A.†	—	21,079	18,943	90·2	—†	89·9	18,943	16,381	415	360
4	"	220	1259	1504	1398	21·1 " A.†	—	21,762	19,726	89·7	—†	90·6	19,726	17,057	432	374
5	"	230	1259	1551	1443	28·1 " A.†	—	22,138	20,978	91·3‡	—†	94·8	20,978	18,174	460	399
6	"	240	1259	1550	1442	25·9 " A.†	—	23,040	20,951	87·3	—†	90·9	20,951	18,149	459	398
7	"	220	1259	1525	1418	26·5 " A.	23·2	21,762	20,250	92·0	872·9	93·0	20,250	17,549	445	385
8	1·7-in., 7.–13. 4. 74.	220	1259	1420	1321	20·6 " 1	19·3	21,762	17,598	80·0	911·8	80·9	17,598	15,230	386	334
9	"	230	1259	1455	1353	20·3 " 1	18·7	22,138	18,476	80·3	988·0	83·5	18,476	15,977	406	351
10	"	240	1259	1470	1366	20·9 " 1	19·5	23,040	18,860	78·6	967·2	81·9	18,860	16,285	414	357
11	1·5-in., No. 2 batch.*	220	1259	1525	1418	25·5 " A.	21·5	21,762	20,250	92·0	941·9	93·0	20,250	17,549	445	385
12	30. 9.–2. 12. 75., mixed, 1·5-in.*	220	1259	1535	1428	26·3 " A.	24·1	21,762	20,564	93·5	853·3	94·5	20,564	17,797	451	391
13	" 1·7-in.	220	1259	1502	1396	25·1 " A.	22·9	21,762	19,637	89·3	857·5	90·2	19,637	17,009	431	373
14	" 2-in.	220	1259	1493	1388	24·8 " A.	22·2	21,762	19,455	88·4	876·3	89·4	19,455	16,814	427	369
15	" 1·7-in.	230	1259	1543	1435	26·6 " A.	24·9	22,138	20,780	90·3	834·5	93·9	20,780	17,972	456	395
16	" 2-in.	230	1259	1498	1392	25·4 " A.	23·4	22,138	19,585	85·0	836·9	88·5	19,585	16,911	430	371
17	" 2-in.	240	1259	1516	1409	24·9 " A.	23·0	23,040	20,058	83·6	872·1	87·1	20,058	17,327	440	380
18	" 1·5-in.	220	1465	1440	1353	30·0 " A.	28·1	21,762	21,058	95·7	749·4	96·8	21,058	18,591	462	408
19	" 1·7-in.	220	1465	1414	1330	26·9 " A.	25·1	21,762	20,305	92·3	809·0	93·3	20,305	17,964	446	397
20	" 2-in.	220	1465	1366	1286	27·3 " A.	24·4	21,762	18,950	86·0	776·6	87·1	18,950	16,795	416	369
21	" 2-in.	250	1259	1523	1416	26·6 " A.	24·8	23,656	20,244	81·0	816·3	85·6	20,244	17,499	444	384

* Re-worked from L.G. † Fired by R.G.F. Pressure only recorded on a crusher in cup at end of bore, and in base of projectile before the gun was bored for crusher gauges. ‡ Cartridge rammed home very hard this round.

results. The first five columns speak for themselves: the sixth gives the maximum pressure observed in the bore. It will be remarked that except in three rounds—all of which were fired with a very mild powder—the greatest strain occurs at A; that is, on the gauge placed in the axis, in the centre of the bottom of the bore. The gauges 1, 2, 3, &c., are placed in the walls of the gun at 1, 2, 3, &c., feet from the bottom of the bore; and since the cartridge, when rammed home, takes up a little more or less than 3 ft.—according to the charge—the mean pressure in the powder-chamber will be gathered from the indications given by the gauges A, 1, 2, and 3. Column 7 is thus formed.

Before entering upon the information given by a comparison between columns 6 and 7, it will be convenient to describe the powders employed. The ingredients are in the same proportion and mixed in the same way as in the L.G., the R.L.G., and the Pebble powders used in the service. The differences consist in the density and size of grain. With regard to density, though it is found desirable in manufacture to vary it according to circumstances, yet in the large cubical powders now in question it never falls below 1·75, whereas the L.G. and R.L.G. powders are considerably lighter. Size of grain is the true controlling element, and the three sizes tried in the 80-ton gun rise from cubes of 1½ in. edge, weighing about six to the pound, to cubes whose edge is 2 ins., weighing about five to 2 lbs.

Powder is not properly so much an explosive, as a substance burning with great rapidity. It offers in this respect a marked contrast to gun-cotton, dynamite, and other true explosives. If one of these agents be detonated, the detonation is immediately carried through the mass, whatever its size, and the whole at once turns into gas. Gunpowder, on the other hand, as far as is known at present, cannot be detonated; but simply evolves its gas by burning in layers from the outside to the inside. It will be readily understood that a large grain will take longer to burn up and become entirely converted into gas than a small one will, and hence the new cubical grains of large size give off their gas with deliberation sufficient to permit the shot to move quietly away before excessive pressures can be set up.

If a powder is of too violent or rapidly-burning a character, a vibratory or "wave" action will be induced in the chamber, and this it is particularly desired to avoid, as it is injurious to material and useless towards the production of velocity. The ideal powder would be one which should burn slowly and regularly, giving off its gas so as to yield gradually increasing pressures equal in all parts of the powder-chamber at the same time. In other words, the figures in column 6 and column 7 of table C should be identical. The greater the difference the less suitable is the powder; though, since perfection can never be reached, a slight departure from uniformity must be tolerated if good velocity be obtained.

It was decided by the Committee on Explosives that no charge should be considered admissible which gave a mean pressure in the powder-chamber exceeding 25 tons on the square inch; and the powder which would give the highest velocity, without exceeding this strain and without departing greatly from uniformity of action, would evidently be

considered as most suitable to the calibre. An inspection of table C will show that, on the whole, the cubes having a 1·7-in. edge and re-worked from L.G. powder proved the best. For the full explanation of column 8, I must refer to p. 133 of the truly admirable treatise on "Fired Gunpowder," recently published in the "Philosophical Transactions of the Royal Society" by Capt. A. Noble, of Elswick, and Professor Abel—a treatise which forms a distinct step in advance in the science of gunnery. Captain A. Noble there gives most comprehensive explanations of the action of gunpowder in the bore of a gun, and shows how to compute the work actually performed by the conversion of the solid into gas. This work is calculated by Capt. Jones in column 8, and column 9 gives the amount realised, which is obtained from the *vis viva* of the shot on leaving the muzzle. The difference is occasioned by the heating of the gun and projectile, the friction, the escape through the vent, and the work done in expanding the gas-check. This last loss, however, is far more than compensated by the saving of escape round the projectile. Column 10 gives the amount of work got out of every pound of powder. The greater the disproportion between the weights of cartridge and shot, other things being equal, the more work will be obtained from each pound of the charge. Column 11 gives the ratio of pressure to work realised. In considering this column it must be borne in mind specially that the relation will be represented by an ascending curve—that is, that as the velocity increases, a greater increment of pressure is required to produce a constant increment of velocity.

Column 12 gives the per-centage of theoretic effect actually realised, being the ratio between columns 8 and 9. Column 13 is the energy ($= \frac{1}{2}$ *vis viva*) of the shot on leaving the gun, and is of course identical with the work realised; while column 14 gives the calculated energy of the shot at a range of 1000 yds., the difference being the loss occasioned by the resistance of the air.

Columns 15 and 16 are given to suit the formula for penetration put forward by Major W. H. Noble, R.A., who considers that, other things being equal, the resistance offered by armour varies with the first power of the shot's diameter.

The powder consisting of 1·7-in. cubes of re-worked L.G. also established a clear superiority when shot weighing 1460 lbs. were employed. (See rounds 18, 19, 20.) These were fired in order to connect the experiments in the 14½-in. calibre with those to be carried out after boring up the gun to 15 ins.

I do not propose in this paper to enter at all upon the question of rifling. The 80-ton gun in its 14½-in. calibre was rifled with eleven grooves, having a spiral which increased from 0 at the breech to 1 turn in 35 calibres at the muzzle, the curve being a parabola. This is precisely similar to the system adopted in the 11-in., 35-ton, and 38-ton guns of the service, in which it has given good results; and as firing into the Proof Butt yields but scanty information on this particular subject, nothing would be gained by enlarging on it in connection with the experiments hitherto carried out with the 80-ton gun.

Turning back for a moment to the problem set by the Admiralty at

the outset—viz., to produce a gun whose projectile shall be able to pierce 20 ins. of well-backed iron at 1000 yds.—let us see how we stand. Of the various calculations for penetration before mentioned, that put forward by Major W. H. Noble is the most favourable to the gun, and that worked out by Lieut. English, R.E., is the most favourable to the plate. It must not be forgotten that the dimensions of the gun were determined on the basis of a 16-in. calibre, throwing a 1650-lb. shot with a muzzle velocity of 1400 f.s. We have already got a 1260-lb. shot starting at 1543 f.s., and a 1465-lb. shot at 1440 f.s. Hence it is as certain as anything connected with powder can be said to be certain, that we shall be able considerably to exceed the anticipated velocity in the 16-in. calibre. Our powers of predicting results have been very greatly increased by Capt. A. Noble's "Researches on Fired Gunpowder," alluded to above; and as far as calculation may be trusted, we ought to get in a bore of that size a muzzle velocity of 1535 f.s. with a 1650-lb. shot, or of 1488 f.s. with an 1800-lb. shot. Now, the gun in its present state at 1000 yds. will penetrate according to

	ins.
Lieut. English	$18\frac{1}{4}$
Major Noble	$23\frac{1}{2}$

while in its 16-in. calibre, if the power expected as above be realised, the penetration at 1000 yds. with 1650-lb. shot will be, by

	ins.
Lieut. English	20
Major Noble	26

and finally, with 1800-lb. shot, by

	ins.
Lieut. English	$20\frac{1}{2}$
Major Noble	27

From this result, it seems that in all probability the gun will be successful in performing the task allotted to it; and it only remains for me to state, in conclusion, that if, after all, it turns out that it cannot do the work, the Royal Gun Factories are quite ready to make one that can.

January 19, 1876.

INSTRUMENTS EMPLOYED BY THE COMMITTEE ON EXPLOSIVES FOR INVESTIGATING THE ACTION OF GUNPOWDER IN THE BORES OF GUNS.

BY

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During the past few years, immense progress has been made in the investigation of the action of fired gunpowder, resulting in considerable improvement in the descriptions of powder employed in the service, and a great increase in the power and safety of our heavy guns. Up to the year 1869, however, when the Committee on Explosives was first appointed, there is no question but that England was behind-hand in the matter of powder, and that the R.L.G. then used—which had been introduced for the B.L. rifled guns—was quite unsuited for the large charges fired from heavy rifled guns. The subject had been under the consideration of a special committee, whose experiments had led to the recommendation of a powder known as "pellet" powder, the grains of which were exactly uniform in size and shape. This pellet powder was, however, never issued in any large quantity, though nominally adopted into the service for heavy guns. The introduction of the present service pebble powder, in 1870 (consisting roughly of cubes of about 0·5 in. edge), was a decided step in the right direction, but the experiments since carried out with the 38-ton and 80-ton guns have shown clearly that the size of even this comparatively large-grained powder must be further increased to render it suitable for the enormous charges fired from these pieces of ordnance. The methods of investigation, and the instruments employed for this purpose, I propose to describe in this paper, referring those who wish for detailed information on the question of powder to the papers which have appeared, from time to time, in these "Proceedings," and to the Reports of the Committee on Explosives.

The methods of investigation may be divided into three sections:—(1) measuring the velocity of the projectile just after leaving the muzzle of the gun; (2) ascertaining the *maximum* pressure exerted by the powder gas on the bore of the gun at certain definite positions; and (3) measuring the velocity of the projectile at several successive points in its passage through the bore, and calculating therefrom the *mean* pressure exerted by the gas at these points.

(1) The muzzle velocity is measured by means of a chronograph invented by Major Le Boulengé, of the Belgian artillery, which has almost entirely superseded the Navez-Lours' instruments, employed with so much success for many years; (2) the pressure at any point in the bore is recorded by a "crusher gauge," inserted in the gun at that point. I have placed these two instruments before (3) the Noble chronoscope (employed for measuring the velocity inside the bore), as they are much oftener and more generally used, having been adopted, both in this country and in India, for proving all cannon powder passed into the service. I shall commence, therefore, with

I.—THE LE BOULENGÉ CHRONOGRAPH.*

Principle of Action.

Major Le Boulengé, in common with all successful inventors of instruments for accurately measuring the velocity of projectiles, makes use of electricity as his agent.

The shot is made successively to cut two currents, and thus to demagnetise two electro-magnets which had previously supported two heavy bodies. The fall of these bodies, under the action of gravity, is the measure of the time taken by the shot to pass over a known distance.

In the Navez and Navez-Leurs instruments the weight liberated by the shot is a pendulum oscillating in front of a graduated arc, the angle described by the pendulum being the measure of the time.

In the Le Boulengé instrument, however, the weight falls *freely*, and without any disturbing influence, in a vertical direction, and the distance actually described by it is measured; the corresponding time being readily ascertained, and the velocity calculated.

By means of a scale previously prepared, the velocity of the projectile can at once be read off without any calculation—an advantage which this instrument possesses over all others.

Every part of the chronograph is of metal, and it is consequently little influenced by changes of climate—a property which renders it peculiarly suitable for use in a country like India, where vulcanite and other insulating materials rapidly deteriorate.

1. The Instrument.

The Le Boulengé chronograph has been invented for two distinct purposes —viz., (1) for taking the velocity of projectiles, (2) for measuring any short intervals of time.

The instrument is set up, when used for taking velocities, as in Plate I., Fig. 1.

It consists of a hollow brass column, *S*, which supports two electro-magnets, *A*, *B*, and a small bracket, *K*. The column stands on a triangular base, upon which is fixed the "*trigger*," *T*. (Fig. 7, Plate II.)

The *electro-magnet*, *A*, supports a long cylindrical rod, *C* (Plate I., Fig. 1), suspended vertically and called the "*chronometer*." This rod is partially covered with two zinc tubes, *D*, *E*, called "*registers*."

The *electro-magnet*, *B*, sustains a shorter rod, *F* (Plate I., Fig. 1), named the "*registrar*."

The "*trigger*," (Plate II., Fig. 7) consists of a circular steel knife, *G*, fixed in a recess of the spring, *H*, by means of the screw, *N*, which forms an axle upon which it can be turned so as to bring a fresh portion of the edge opposite the chronometer.

The spring, *H*, can be "cocked," or restrained, by means of the catch on one end of the lever, *I*.

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* The following description is re-written up to date from a paper published by the War Office, in 1870, under the following title:—"Description and Use of Le Boulengé's Chronograph. Translated from a Memoir by the Inventor, Captain-Commandant P. Le Boulengé, of the Belgian Artillery, with some additional Explanations, and the Results of Experiments made at Waltham Abbey in comparison with the Navez-Leurs' Instrument, by Lieut. C. Jones, R.A., Instructor Royal Gun Factories."

The other end of this lever carries a disc, *O*, fixed to a screw, by means of which it can be raised or lowered as required.

This disc is vertically below the registrar when suspended to its electro-magnet; consequently, when the current through the second screen is broken, the registrar falls on the disc, and releases the spring, *H*.

The tube, *L* (Plate I., Fig. 1), retains the registrar after its fall.

If it be required to alter the time taken by the registrar to release the knife, it is done by raising or lowering the disc of the trigger by turning it in the direction with the *sun* to *increase* the time, and *against the sun to reduce* it.

The screw has a pitch of one millemètre, and the circumference of the disc is divided by notches into ten equal parts, in which the paul, *P*, works. By this arrangement the disc can be moved any required number of tenths of a millemètre (within certain limits), and is retained in the required position by the paul.

The screw, *M*, passes through the lever, and acts against the fulcrum supporting it. It is intended for regulating the hold of the catch of the lever on the spring, which should always be as light as possible.

This is regulated once for all; but should the spring at any time show a tendency to escape of itself, this defect can be remedied by slightly withdrawing the screw, *M*.

The *disjunctor* (Plate II., Fig. 9) is composed of a mainspring, *t*, carrying a cross-piece, *u*, covered with insulating material, and passing under the two steel plates, *q q'*. By pressing the milled-headed screw, *z*, the spring is compressed and held by the catch, *x*, allowing the plates, *q q'*, to come into contact with the metal pins, *r r'*, and thus complete the circuits by bringing the screws, *s v* and *s'v'*, into connexion with one another. When the catch, *x*, is pressed, the mainspring being released, its cross-piece strikes the two plates exactly at the same instant, raises them from the screws, and thus breaks both currents identically at the same time.

Should it be thought at any time that the disjunctor is working inaccurately, the method of testing it, and of correcting it when out of order, is very simple, and will be described under the heading of "Method of Correcting Irregularities."

The arrangement of the screens and electric current is precisely the same as when using the Navez-Leurs instrument, except that the chronometer battery must be increased in strength (because its electro-magnet is required to support a greater weight than in the Navez-Leurs instrument), and a different method must be adopted for introducing the disjunctor into the circuit (Plate III.) With the Le Boulengé chronograph, the two wires from the positive poles of the batteries are not joined as with the Navez-Leurs, but are taken to the two connecting screws, *s s'*, of the disjunctor; and thus the two currents, though passing through the disjunctor, are kept entirely separate. (Plate III.)

The electro-magnet, *A*, is magnetised by the current passing through the first screen; consequently, when the shot cuts this screen the *chronometer* is released and falls freely in a vertical direction.

The other electro-magnet is in the circuit through the second screen, so that the *registrar* falls when this screen is cut, and, striking the disc on the free end of the lever of the *trigger*, liberates the spring, which carries forward the knife until it strikes the chronometer in its fall and makes an indent in the upper zinc tube.

A very simple relation exists (as will be seen hereafter) between the height of this indent and the velocity of the projectile. It is evident that the time which elapses after the fall of the chonometer before the registrar is released is the time taken by the projectile in passing over the distance between the screens; the less, therefore, the velocity of the projectile, the further in advance will the chronometer be, and the higher will be the indent.

A graduated rule is used for measuring the height of the indent above the zero point. It is of brass, and is graduated on both edges; the upper edge is a scale of equidistant parts, divided into inches and tenths, reading to thousandths with a vernier, and is intended for use in connexion with the tables.

The lower scale is for reading off the velocity of the projectile without any calculation. It is graduated in feet for a distance between the screens of 120 ft.

The zero point on the scale corresponds with the "*origin*," or the point at which the knife marks the zinc if the trigger is set in action when the chronometer is at rest.

The rule is fitted at the zero end with a jointed piece having a slightly conical projection, which enters into a recess in the bob of the chronometer when applied for measuring the marks. Care must be taken not to injure this portion of the scale or the measurement may be rendered inaccurate.

2. Theory of the Instrument.

As stated above, if the trigger be set in action when the chronometer is at rest, a mark will be made by the knife on the zinc, which point we will call the "*origin*," as it is the zero point from which the height of fall of the chronometer must be calculated.

Let H be the height above the origin of the mark obtained by firing a projectile through the screens. Since the chronometer follows the law of the fall of heavy bodies,

$$T', = \sqrt{\frac{2H}{g}},$$

will be the time it was in motion before receiving the impression. Now, T'' would be the time required by the projectile to traverse the distance between the screens, supposing that the chronometer commences to fall the instant the projectile passes through the first screen, and further, supposing that it is struck by the knife at the precise instant the shot cuts the second screen. But this is not the case. In fact, after the rupture of the first screen, a certain time, θ, elapses before the electro-magnet is demagnetised sufficiently to free the chronometer; the movement of the chronometer will therefore be delayed, and the observed time consequently diminished, by the quantity θ.

Again, some time elapses between the cutting of the second screen and the moment when the knife reaches the chronometer—viz., the time required for the following operations:—

θ' for the demagnetisation of the electro-magnet supporting the registrar.
t' for the fall of the registrar to the disc of the trigger.
t'' for the disengagement of the catch.
t''' for the knife to pass over the horizontal distance which separates it from the chronometer.

Now, it is evident that the chronometer, before it is struck by the knife,

will have been in motion during the sum of the above time in addition to the time taken by the shot in passing over the distance between the screens. Consequently, the observed time T' is too great by the sum of $(\theta' + t' + t'' + t''')$. We have also shown above that T' is too small by the quantity θ—the time required to demagnetise the chronometer electro-magnet. Therefore, to ascertain the true time T, we must deduct from T' the quantity $(\theta' + t' + t'' + t''' - \theta)$, which we will call t.

We have then $T = T - t$.

Now, suppose $T = 0$, or, in other words, suppose the shot to cut both screens simultaneously, then we should have $T' = t$. From which it appears that t would be the time recorded on the chronometer if both currents were cut identically at the same instant. This we can do by using the disjunctor, and we thus obtain a mark, on the lower zinc tube, at a height above the origin equal to the space passed over in the time t, which we call the *disjunctor reading*. The time corresponding to this reading must be deducted from the whole time recorded on the chronometer, to arrive at the time taken by the shot to traverse the distance between the screens. As before stated, the disc of the trigger can be raised or lowered so that the disjunctor reading can be altered (if required) within certain limits, and we can thus regulate the instrument so that the time t shall have a constant value. The value of t for which the velocity scale has been calculated is 0·15 of a second, and the height of the corresponding mark above the origin is 4·345 ins. (110·370 mill.) Starting with this assumption, a scale has been calculated for a distance between the screens of 120 ft., by means of which the velocity of the projectile can be at once determined without the aid of any calculation. Should it be necessary to place the screens nearer to one another, the velocity can be found by multiplying the number read off on the scale by the fraction $\frac{D}{120}$, D being the actual distance between the screens in feet.

The method of calculating this scale is as follows:—

Suppose the shot to have a velocity of 1200 ft. a second, it would take $\frac{120}{1200} = 0''\cdot1$ to traverse the distance between the screens.

The instrument will, therefore, mark $0''\cdot15$ (disjunctor reading) $+ 0''\cdot1$, or $0''\cdot25$, and the corresponding height of fall from the origin will be

$$H = \tfrac{1}{2}gT'^2 = \frac{g \times \overline{0\cdot25}^2}{2} = 12\cdot075 \text{ ins.}$$

Conversely, if the mark on the chronometer is 12·075 ins. above the origin, we know that the velocity of the projectile is 120 ft. a second; the disjunctor reading being at a height corresponding to $0''\cdot15$, and the screens 120 ft. apart.

This calculation has been made for a series of velocities increasing from foot to foot for velocities from 850 to 1500 feet a second, and increasing by 5 ft. from 1500 to 1800 ft. a second, and the corresponding heights engraved on the scale supplied with the instrument.

3. Method of Adjusting the Instrument.

Setting up the Chronograph.

For transport, the different portions of the instrument are packed in a box, which can be made to serve the purpose of a stand (as shown in Plate I.), by means of an iron tripod supplied with it.

This arrangement is no doubt very convenient in cases where it is required to move the instrument constantly, and to set it up in different positions. For proving powder, or in similar cases, where the instrument is stationary, it is advisable to have recourse to a more permanent arrangement. The plan adopted at Waltham Abbey is to form a stand by driving four piles 9 ft. into the ground, on the top of which is placed a solid oak block, 15½ ins. square and 2½ ins. thick, so as to form a permanent stand 3 ft. 6 ins. high.

The piles are out of contact with the floor or walls of the room, to prevent vibration being communicated to the instrument.

The triangular piece which supports the trigger and the column is fastened to a heavy cast-iron base by the three screws supplied with the instrument.

This base is 13 ins. square and 1 in. thick, and is supported on three milled-headed levelling screws, which work in brass V's let into the oak block. The piles are cased with deal to form a box, and a recess is cut in the iron base and the oak top to allow the chronometer to fall into a vertical trough made to receive it.

This trough, as well as the edge of the recess in the iron base, is lined with leather, and it is also padded at the bottom, to prevent the chronometer from rebounding, and the point from being injured by striking against the iron stand. The instrument is permanently fixed to the stand, and is covered, when not in use, by a wooden case, to protect it from injury, a small saucer containing calcined chloride of calcium being used to absorb the moisture under the case.

The electro-magnets are fixed in position by passing the screwed stems through the column and fastening them with milled-headed nuts. Two zinc tubes, or registers, are placed on the chronometer; to put on the small one, the bob at the lower end must first be unscrewed. The tubes should be pressed *slightly* out of shape before being put on, to cause them to fit tightly on the rod, and not to shift too easily. Care must be taken during the operation that the bottom of the tube is resting against the bob.

At Waltham Abbey the disjunctor is fixed by wooden cleats to the side of the shed on the right of the instrument, so as to be in a convenient position for the operator when standing opposite the chronograph.

The connexions with the battery and the screens having been established, and the currents found to pass correctly, and to be of sufficient strength, the next step is to adjust and regulate the instrument.

This consists of three operations, viz. :—

(1) Levelling the instrument.
(2) Regulating the power of the electro-magnets.
(3) Regulating the height of the disjunctor reading.

(1) *Levelling the Instrument.*—For this purpose the chronometer is used. After having cocked the trigger, suspend the chronometer to its electro-magnet, and bring it into its proper position by means of the levelling screws.

In levelling from front to rear, see that the inclined plane on the bob, on the side opposite the number, rests *very lightly* against the projecting edge, *cc*, (Plate II., Fig. 1), of the triangular base.

To level laterally, the right face of the bob is brought exactly in line with the salient angle, *dd*, formed by the projection above referred to. In this

position the left face of the bob is a short distance from the screw, *E*; the edge of the knife is opposite and slightly behind the zinc tube; and when the chronometer falls, the projecting ring *c* (Fig. 1), passes clear of the knife-edge. To test whether this is the case, break the circuit, by means of the disjunctor, and notice whether there is any friction, or if anything catches during the fall.

To ascertain whether the chronometer is properly levelled from front to rear, see that the inclined plane on the bob rests along its whole length against the projecting edge, then remove it sideways out of the vertical, by pushing the bob against the screw, *E*, when it will return into its original position, if properly levelled.

It is of great importance that the instrument should be accurately level, otherwise the distance of the chronometer from the knife-edge will vary during its fall, and the distance the knife has to travel before reaching the zinc will not always be the same; in other words, t''' will not be a constant.

The levelling being completed, and the registrar suspended to its electro-magnet, the inclined plane on the bob, on the side opposite the number, should rest very lightly against the edge of the arm, *K*. This arm is fitted in a bracket, and its position can be altered by means of an adjusting screw. This adjustment need only be performed once for all ordinary positions of the instrument when used in taking velocities.

(2) *Regulating the Electro-Magnets.*—This is done (as with the Navez-Leurs instrument) by withdrawing the core of the magnets until they are only capable of just supporting the rods. It is always an advantage to work with weak magnets, as the variation in the time required to demagnetise them need not be taken into account; should, however, their power be insufficient, the operator will experience some difficulty in suspending the rods.

The following method has been adopted for making the electro-magnets of just sufficient power:—

The chronometer, with its zinc tubes, is increased in weight by means of a brass tube one-tenth the weight of the chronometer, which is slipped over the upper zinc. It is then suspended to the magnet, and the core gradually withdrawn until the power is insufficient to support the weight, when it falls. The core must be turned slowly and gently, so as not to free the rod by any jar or vibration, and it is well to ascertain that the rod has not been shaken down by offering it to the magnet a second time before removing the extra weight. The extra weight is then removed, and the chronometer can be suspended without difficulty.

The other magnet is regulated in the same manner, a smaller brass tube being supplied for increasing the weight of the registrar.

In order to suspend the chronometer to its electro-magnet without difficulty, the following method should be adopted:—Hold it lightly in the left hand at the centre, the fingers open and towards the body; allow the bob to rest upon the second joint of the first finger of the right hand, the hand being half open, the palm vertical and turned towards the body, and the fingers together; the chronometer is thus held in a vertical position, the numbered face of the bob being turned towards the operator. Bring it, in this position, to the electro-magnet, by placing the exterior surfaces of the two cones in contact, and, as soon as attraction is perceived, let go with the left hand, still keeping the fingers near to catch the chronometer should it fall. Then slowly lower the right hand, so that the two cones, sliding over

one another, remain with their points only in contact, and place the bob in its proper position by moving the first finger of the right hand, upon which it still rests. This done, withdraw the support of the right hand by lowering it vertically, when the chronometer will remain suspended in its proper position. If there should be any vibration, it will soon cease from the friction against the rest.

The registrar is suspended in the same manner, but the *chronometer is always placed in position first.*

Difficulty is sometimes experienced by beginners in suspending the parts of the chronograph; minute details have therefore been given as to the best way of doing so, and these should be strictly adhered to.

The other operations are exceedingly simple.

To cock the disjunctor, so as to establish the currents, press the milled-headed screw *z* (Plate II., Fig. 9) with the centre finger of the right hand, until the spring is held by the catch *x*.

To break the currents, press the catch, *x*, with the forefinger of the right hand, the thumb being placed against the support, *y*.

In cocking the trigger, care must be taken not to disturb the level of the instrument; consequently the left hand only is used, the fingers being placed against the support of the tube, *L* (Plate I.), and the spring drawn back with the thumb until it is held by the claw of the lever.

The trigger must always be cocked before attempting to suspend the chronometer.

(3) *Regulating the disjunctor reading.*—As we have said before, this reading should represent a time $= 0''\cdot15$, and the mark should consequently be 4·345 ins. above the origin. This height is shown on the scale by a special mark, called "*disjonctor.*" To facilitate the operation, commence by tracing on the small zinc tube a circle at the required height. For this purpose fasten the vernier by means of the clamping screw, with the index opposite the line marked "disjonctor." Place the chronometer flat on a table with the numbered face next the body, and apply the rule to it, by inserting the conical point of the hinge in the recess of the bob, allowing the index of the vernier to rest on the zinc. Support the end of the rule in the right hand, and, with the left, turn the tube, taking care to keep it pressed against the bob at the lower end of the chronometer. In this manner a fine line is traced on the tube, with which, when the instrument is well regulated, the disjunctor marks ought to correspond.

The indent made by the knife is a notch, clearly cut in the metal, the base of which is in a plane, perpendicular to the axis of the tube. It is the section of this plane with the tube which must be taken as the mark, and the index of the vernier must always be brought against the small step at this point when reading the height of the indent.

The point of the vernier index is of the same form as the edge of the knife, and consequently fits accurately against the plane (or lower) side of the indent, so that there can be no uncertainty in the measurement.

The instrument having been prepared, a disjunctor reading is taken; if the mark is exactly on the circle previously traced, and several repetitions show no variation, no alteration is necessary, and the experiments can be proceeded with at once.

Should the mark, however, be above the circle, the space through which

the registrar falls must be diminished by raising the disc of the trigger; if below, the disc must be lowered. In the former case it is turned in the contrary direction to the sun, and in the latter case with the sun.

The arrangement by which the amount of alteration in the height of the disc is regulated has already been pointed out when describing the trigger (p. 356). When the height of the disc has been regulated for some previous experiments the reading will not vary on another occasion more than a few tenths of a millemètre, and this can be (at once) corrected by turning the disc, in the proper direction, through the required number of divisions of the circle.

4. Method of taking Velocities.

The instrument is prepared for measuring velocities in the same manner as for taking the disjunctor reading. First cock the disjunctor, then the trigger, and afterwards suspend the chronometer and registrar. Before suspending the rods, however, it is advisable, in order to prevent the possibility of errors in measuring the indents given by different rounds, to make marks round the lower edge of the upper zinc tube, about $\frac{1}{20}$th of an inch apart, and to turn the tube after each round so as to bring these marks successively opposite the line *ab*, on the centre ring *c* (Plate I.) Equidistant lines are thus obtained, upon which the marks of successive rounds will be registered.

The same may be done with the lower (or disjunctor) tube. By this means each tube can be made to register about twenty indents at each end, and can be turned end for end when the circle at one extremity is completed.

An indent having been obtained on the upper tube by firing a projectile through the screens, the velocity may be ascertained in two ways:—1st, by measuring the height of the mark above the origin, and calculating the time and corresponding velocity from the tables; 2ndly, by measuring the velocity on the scale adapted for that purpose.

The former method is the more accurate, while the latter takes less time, and for all ordinary purposes indicates the velocity within sufficiently narrow limits.

5. Method of correcting Irregularities.

When the foregoing directions for adjusting and regulating the instrument are adhered to, not only do successive disjunctor readings taken between the rounds agree within very narrow limits, but the readings generally remain constant from one round to another. It is therefore sufficient, when accustomed to the chronograph, in order to ensure its regularity, to take a reading of the disjunctor after every three or four rounds.

The operator must judge from the regularity of these readings whether he should repeat them, and whether it may be necessary to readjust the instrument.

The following directions will assist him:—If the reading is too high, or too low, repeat it, and if the difference remains constant, and is small, the height of the disc of the trigger need only be altered. Should, however, the error be considerable, indicating that there is a variation in the force of one of the magnets, this force must be regulated.

Should the disjunctor readings become irregular, the following points must be looked to, viz:—

(1) If one of the magnets has not become too strong.
(2) If the instrument is properly levelled; that is, if the rods hang vertically, and do not rest too heavily against the support.
(3) If there be not an imperfect connexion in the circuits, including the battery and the screens.

Should the mark obtained be indistinct, the chronometer must be brought nearer to the knife (by means of the levelling screws), care being taken that it still falls freely and without friction.

If, during the experiments, one of the currents becomes broken without any apparent cause, try (after ascertaining that the screens are properly mended) whether there is contact between the plates, q q', of the disjunctor (Plate II., Fig. 9) and the pins, r r', by removing the wire from the binding screw at one extremity of the plate, and bringing it into contact with the screw at the other end. If the current is thus re-established, it shows that the break occurs at the point of contact of this plate with the screw, which should be cleaned by passing a piece of paper between them.

The only parts of the instrument that require special attention are the conical points of contact between the rods and the electro-magnets.

These four points ought to be kept clean and polished, and it is as well never to touch them with the fingers, and to rub them frequently with a chamois leather. The rest of the instrument may be covered with rust and dirt without affecting its working, whilst a single spot of rust on one of these points may cause irregularity in the disjunctor readings. If by accident they should get rusty, very fine emery cloth must be used to clean them, care being taken to rub round the point so as not to alter its form.

From the nature of the instrument itself, nothing can affect the chronometer while falling, and the rate of falling being according to a well known and invariable law, it is evident that there can be no *constant error* in the measurement of velocities, provided that the scale is correctly graduated, and the disjunctor is in proper working order.

The *accidental errors* which may be committed correspond to those which occur when a series of disjunctor readings are taken, after the instrument has been properly regulated; and any one at all accustomed to using the instrument will see at once that the errors in determining velocities (including errors in reading the scale) do not exceed a few thousandths of an inch, and that the results are sufficiently accurate for ordinary experiments, the variations being far less than those due to other causes.

If the two currents are not broken by the disjunctor identically at the same instant, there will be a *constant error* in the readings. The disjunctor is not liable to get out of order, but, if required, its accuracy can at any time be verified as follows:—

Determine the height of the disjunctor reading, and then invert the currents by removing the wires which were first at s and v to s' and v', and those at s' and v' to s and v (Plate II., Fig. 9), so as to send the chronometer current through the side on which the registrar current first passed, and *vice versâ*. Having done this, take several readings, and ascertain whether they agree

with those previously taken, which will be the case if the disjunctor is correct.

If there should be any difference between the height of these two series, it represents *double the error* of the disjunctor, and from the relative position of the marks it can be seen on which side contact is first broken—*i.e.*, which plate is raised before the other. To correct this error, it is only necessary to elevate or lower one of the screws, *v v'*, until both plates are raised by the cross-piece of the spring exactly at the same instant.

6. Comparison with the Navez-Leurs and other Instruments.

The following table gives the results of a comparative trial of the Le Boulengé and Navez-Leurs chronographs. The instruments were both introduced into one and the same circuit through the screens, so that the velocity of each shot was simultaneously recorded on each of them.

Table of Comparison between the Navez-Leurs and the Le Boulengé Chronographs.

Nature of powder and charge.	Velocity by Navez-Leurs at 105 ft.	Velocity by Le Boulengé at 105 ft.	Difference.	Nature of powder and charge.	Velocity by Navez-Leurs at 105 ft.	Velocity by Le Boulengé at 105 ft.	Difference.
R.L.G. powder, W.A. Charge 1 lb. Shot 12 lbs., fired from 12-pr. M.L.R. gun.	951	950	+ 1	R.L.G. powder, W.A. Charge 1 lb. Shot 12 lbs., fired from 12-pr. M.L.R. gun.	1009	1004	+ 5
	933	927	+ 6		1003	996	+ 7
	943	938	+ 5		998	993	+ 5
	942	938	+ 4		998	993	+ 5
	962	959	+ 3		1005	1001	+ 4
	985	981	+ 4		1020	1014	+ 6
	983	977	+ 6		1019	1015	+ 4
	998	992	+ 6		1021	1019	+ 2
	983	978	+ 5		993	988	+ 5
	988	986	+ 2		998	993	+ 5
	979	975	+ 4		1018	1013	+ 5
	973	970	+ 3		1020	1018	+ 2
	976	980	— 4		1017	1013	+ 4
	993	989	+ 4		1017	1014	+ 3
	987	985	+ 2		992	987	+ 5
	982	979	+ 3		990	986	+ 4
	990	988	+ 2		993	988	+ 5
	993	995	— 2		989	983	+ 6
	998	1001	— 3		1009	1006	+ 3
	986	990	— 4		1003	997	+ 6
	965	963	+ 2		1006	1001	+ 5
	962	959	+ 3		1003	999	+ 4
	972	971	+ 1		993	989	+ 4
	961	958	+ 3		998	993	+ 5
	951	950	+ 1		991	985	+ 6
	987	986	+ 1		998	995	+ 3
	1023	1019	+ 4		1006	1003	+ 3
	1017	1013	+ 4		1001	997	+ 4
	1023	1020	+ 3		1002	999	+ 3
	1005	1001	+ 4		1002	999	+ 3
	1008	1004	+ 4		991	992	— 1
	998	991	+ 7		995	994	+ 1
	1008	1002	+ 6		980	977	+ 3
	1008	1003	+ 5		977	978	— 1
	1015	1008	+ 7		983	979	+ 4
	1021	1016	+ 5		981	979	+ 2
	1017	1012	+ 5		998	996	+ 2
	1019	1015	+ 4		990	990	0
	1003	999	+ 4		996	995	+ 1
	1008	1006	+ 2		989	988	+ 1

(*Continued.*)

Nature of powder and charge.	Velocity by Navez-Leurs at 105 ft.	Velocity by Le Boulengé at 105 ft.	Difference.	Nature of powder and charge.	Velocity by Navez-Leurs at 105 ft.	Velocity by Le Boulengé at 105 ft.	Difference.
R.F.G. powder, W.A. Charge 85 grs. Bullet 480 grs., fired from Henry rifle.	1257	1266	— 9	R.F.G. powder, W.A. Charge 85 grs. Bullet 480 grs., fired from Henry rifle.	1244	1246	— 2
	1249	1256	— 7		1255	1250	+ 5
	1257	1263	— 6		1257	1257	0
	1233	1241	— 8		1251	1251	0
	1262	1269	— 7		1249	1251	— 2
	1271	1276	— 5		1284	1275	+ 9
	1253	1249	+ 4		1273	1271	+ 2
	1267	1267	0		1281	1275	+ 6
	1258	1262	— 4		1265	1259	+ 6
	1254	1251	+ 3		1245	1250	— 5
	1266	1263	+ 3		1251	1255	— 4
	1266	1266	0		1259	1257	+ 2
	1260	1259	+ 1		1258	1257	+ 1
	1266	1266	0		1247	1254	— 7
	1253	1257	— 4		1254	1257	— 3
	1273	1272	+ 1		1258	1258	0
	1263	1267	— 4		1254	1257	— 3
	1263	1274	—11		1249	1247	+ 2
	1259	1270	—11		1254	1259	— 5
	1255	1262	— 7		1255	1254	+ 1
	1254	1255	— 1		1261	1259	+ 2
	1254	1262	— 8		1254	1257	— 3
	1256	1260	— 4		1269	1269	0
	1257	1263	— 6		1262	1262	0
	1257	1259	— 2		1263	1266	— 3
	1260	1257	+ 3		1267	1266	+ 1
	1249	1255	— 6		1262	1265	— 3
	1266	1269	— 3		1250	1253	— 3
	1254	1260	— 6		1277	1274	+ 3
	1264	1266	— 2		1258	1259	— 1
	1247	1247	0		1266	1266	0
	1249	1245	+ 4		1261	1259	+ 2
	1238	1240	— 2		1249	1247	+ 2
	1240	1242	— 2		1259	1259	0
	1242	1245	— 3		1266	1265	+ 1
	1243	1245	— 2		1270	1269	+ 1
	1240	1242	— 2		1258	1259	— 1
	1241	1242	— 1		1262	1261	+ 1
	1236	1242	+ 6		1255	1255	0
	1251	1250	+ 1		1273	1274	— 1
	1270	1271	— 1		1240	1240	0
	1267	1270	— 3		1254	1259	— 5
	1254	1255	— 1		1257	1257	0
	1255	1258	— 3				

On reference to the column headed "Difference," it will be seen that the difference between the velocity of any particular round, as indicated by either of the instruments, is very trifling, the variations in the velocity of successive shots being due to the fact that various lots and descriptions of powder were being tested at the same time, and, so far from interfering with the trial of the two instruments, it serves rather to demonstrate more clearly the wonderful agreement in their indications.

For the purpose, however, of more accurately determining the relative value of the two chronographs, the velocity of 50 rounds of various lots of Waltham Abbey R.L.G., and 50 rounds of Waltham Abbey R.F.G. powder, have been taken from the table, and the mean velocity and the mean difference of velocity calculated for each instrument, as follows:—

Instruments.	12-pr.		Henry Rifle.		Difference between the mean velocities given by each instrument.	
	Mean velocity at 105 ft.	Mean difference of velocity.	Mean velocity at 105 ft.	Mean difference of velocity.	12-pr.	Henry Rifle.
Navez-Leurs.....	1004·9	8·88	1259·3	6·11	4·0	2·2
Le Boulengé.....	1000·9	8·69	1261·5	6·12		

From the above calculation it appears that the mean differences of velocity as shown by each instrument (for similar descriptions of powder) are practically equal, though the mean velocity given by the Navez-Leurs instrument is in one case greater and in the other case less than that obtained by the Le Boulengé chronograph.

This variation at different parts of the scale is no doubt due to a slight error in the constant used in the preparation of the tables for one of the instruments; and the fact that the Navez-Leurs instrument had been in constant use for some years without any re-adjustment, is amply sufficient to account for so small a discrepancy in a velocity of nearly 1300 ft. a second.

The accordance between the mean differences of velocity is most remarkable, when we consider that the mechanical construction of the two instruments is totally dissimilar; it proves that they are equally accurate in their working, while, at the same time, it justifies the assumption that their results are both trustworthy.

The object of the above experiment was to test the reliability of the Le Boulengé instrument with a view to its general adoption for the proof of powder, for which purpose it is peculiarly adapted, as, by means of the velocity scale, it can be very readily and rapidly worked, and its construction is so simple that it appears little liable to get out of order.

Since the date of the above comparative trial, the Le Boulengé chronograph has been adopted for general use in ballistic experiments, and more especially for the proof of gunpowder, both at home and in India. These instruments have also been set up by all the leading manufacturers of powder, as, without some such means of testing their powder during manufacture, they find it difficult to produce the high quality now required for our accurately-shooting rifled guns.

In proof of powder, and other experiments at the R.G.F. Proof Butts, it is customary to use two instruments for measuring the velocity of each shot. They are set up side by side, and by using a double set of screens and currents two *perfectly distinct* records of the velocity of each shot are obtained. This arrangement is most useful in furnishing confirmatory evidence of the accuracy of the results given by each instrument. A table is subjoined—taken at random from some of the Committee's experiments with field gunpowders—which exhibits the accordance of the two instruments used at the Proof Butt, when in good order and on a favourable day.

Date of firing, 24th April, 1875. 25-pr. R.M.L. gun, Expl. No. 398. Object of experiment, to test the result of firing different charges from a rear and from a forward vent.

Number of round from gun.	Charge.	Vent.	Observed velocity.		Difference.
			Instrument No. 78.	Instrument No. 79.	
	lbs.		ft.	ft.	
40	4	Rear	1278	1280	2
41	"	"	1280	1282	2
42	"	"	1280	1278	2
43	3	"	1160	1159	1
44	"	"	1170	1169	1
45	"	"	1163	1161	2
46	5	"	1314	1310	4
47	"	"	1309	1308	1
48	"	"	1330	1330	0
49	3	Forward	1156	1157	1
50	"	"	1160	1162	2
51	"	"	1146	1148	2
52	4	"	1297	1297	0
53	"	"	1301	1303	2
54	"	"	1310	1309	1
55	5	"	1400	1401	1
56	"	"	1410	1409	1
57	"	"	1413	1412	1

The mean difference between these two instruments for the above eighteen rounds is only 1·4 ft., representing a maximum error of about $\frac{1}{1000}$th part of the recorded velocity.

As a further evidence of the *absolute* accuracy of the different instruments employed for measuring velocities, I append a trial of these two Le Boulengé instruments in comparison with the small Bashforth gravity chronograph, in use at the Royal Laboratory Small-Arm Range, and an electric chronograph invented by Lieut. H. Watkin, R.A. The Bashforth instrument is described at p. 161, Vol. V., of these "Proceedings," and Watkin's invention at p. 14, Vol. IX.

Velocities of Martini-Henry Bullets fired with Various Charges, observed with several Instruments.

Le Boulengé.		Bashforth.	Watkin.	
Instrument No. 78.	Instrument No. 79.		Right cylinder.	Left cylinder.
1167	1163	1163	1155	1157
1141	1140	1143	1137	1136
1140	1138	1138	1129	1132
1136	1133	1141	1138	1139
1147	1145	1142	1140	1140
Means of 5 rounds 1146	1144	1146	1140	1141
1272	1275	1269	1259	1259
1268	1264	1269	1267	1267
1270	1271	1277	1270	1268
1277	1279	1287	1272	1272
1285	1287	1290	1287	1285
1290	1294	1280	1284	1284
1264	1267	1263	1264	1264
1287	1289	1291	1285	1284
Means of 8 rounds 1277	1278	1275	1274	1273

These results indicate a remarkable concordance between all the instruments, and lead to the conclusion that they are all perfectly trustworthy within practical limits, and that no decided preference (as regards reliability) can be given to any one of them. I prefer the Le Boulengé, however, for ordinary every-day work, on account of its extreme simplicity and facility of manipulation.

II.—THE CRUSHER-GAUGE.

The crusher-gauge is employed, as before stated, for registering the maximum pressure of the powder gas at the particular point in the bore where the apparatus is placed. It superseded the Rodman "pressure-gauge" employed by the Committee on Explosives in their earlier experiments, on account of the extreme variability of the results given by that instrument.

PLATE IV.

THE CRUSHER GAUGE.

Fig. 1.

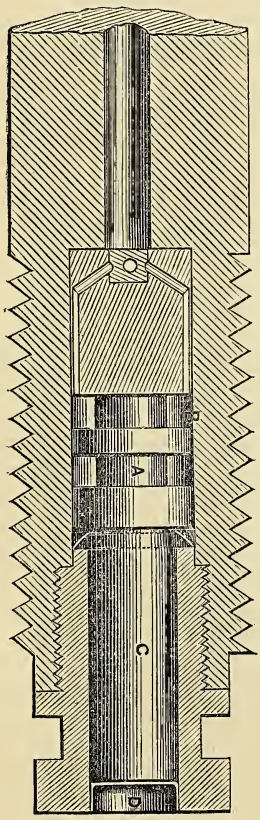
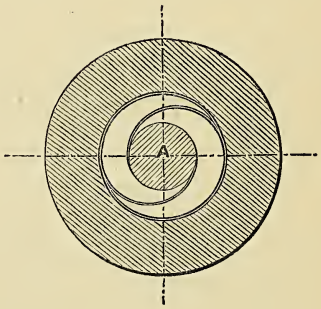


Fig. 2.



This exceedingly simple machine is shown in Plate IV. The idea of ascertaining the pressure by the amount of "crushing" or compression of small cylinders of copper, originated, I believe, in the Royal Gun Factories—in which department these gauges were first manufactured. The instrument consists of a steel bush (Fig. 1), of the same dimensions as the vent-bush used for all our service guns, provided with a moveable base or nozzle screwed on to the bush. The interior of the nozzle is hollowed out so as to form a chamber, in which is placed a steel "anvil," with grooves along its surface communicating with a channel corresponding with the vent-channel in a vent-bush. Thus any gas that may, by accident, find its way into the crusher-chamber has a free escape into the air. This channel has been omitted in the crushers for the 80-ton gun. In this chamber is placed a small cylinder of copper, *A* (Figs. 1 and 2), half-an-inch in length and $\frac{1}{12}$th inch in diameter. This cylinder is held lightly (but not prevented from expanding laterally) in the centre of the chamber, by a small watch-spring. One end rests against the anvil, while the other end is acted on by a piston, *C* (Fig. 1), which is moveable in the nozzle, and is pressed against the copper cylinder by a small spring. The lower end of this piston is $\frac{1}{6}$th inch in area (under ordinary circumstances) and is open to the pressure of the powder gas; a small brass cup, or "gas-check," *D*, being inserted to prevent the gas from penetrating past the piston.

The apparatus is used as follows:—A hole is bored in the gun in the required position (see Plate V.), into which the gauge is screwed until the end of the plug is flush with the surface of the bore. On the explosion of the charge, the copper cylinder is crushed between the piston and the anvil, and the amount of compression is an indication of the pressure exerted by the gas at that point. The actual pressure corresponding to any given compression of the crusher-cylinder is arrived at by compressing a series of similar copper cylinders in the statical testing machine in the Royal Gun Factories, and tabulating the results. It is found that, with proper care in the selection and testing of the copper, the results are very reliable. Where extreme accuracy is required—as in the late experiments with the 80-ton gun—each copper cylinder is tested previous to being inserted in the gauge. This is done by crushing them all up to a given pressure (say 18 tons on the square inch)—rather less than the pressure which the crusher-gauge is expected to record—which method of procedure has the additional advantage of eliminating some irregularities to which the crusher-gauge has been found, under certain circumstances, to be liable. The compression of the cylinder in the crusher-gauge is ascertained by removing the plug from the gun, unscrewing the nozzle, taking out the cylinder, and measuring its length by means of a micrometer reading to the one-thousandth of an inch. A reference to the tabulated results of the previous compression of similar coppers in the testing machine at once gives the pressure in tons on the square inch without any calculation. The gauge is cleaned, a fresh copper cylinder is inserted in the chamber, and the nozzle is screwed home, when the apparatus is ready for immediate use.

In their first Progress Report, dated 5th February, 1870, the Committee on Explosives state "that much greater dependence could be placed upon the results furnished by this apparatus than upon those obtained with the 'Rodman' gauge, and for the following reasons:—

"The shape and size of the 'Rodman' coppers and knives render it imperative to place them at the upper extremity of the plug, and consequently on the exterior of the gun (if muzzle-loading); the gas has, therefore, a considerable space to travel through between the powder-chamber and the instrument. Thus, before reaching the latter, it has attained a high *vis viva*, especially in quick-burning powders; this is transferred to the knife, and the recorded pressures are therefore always much higher than should be the case. This was clearly shown by placing a copper cylinder in one of the Rodman gauges, and comparing its compression with that of a similar cylinder taken from the crushing instrument.

"In the case of R.L.G. powder, the inner cylinder was compressed from 0·500 in. to 0·285 in.; the area on which the gas acted being ·167 of a square inch, and the corresponding pressure 22½ tons per square inch.

"On the other hand, the cylinder placed externally was reduced from 0·500 to 0·251 in.; the gas acting on an area of 0·110 square inch, and the corresponding pressure being 40 tons per square inch.

"The above obstacle to the attainment of correct pressure-indications does not exist in the crusher-gauge, as the small diameter of the working parts of this instrument permits of their being placed near the surface of the bore.

"Another advantage due to its small dimensions consists in the readier attainment of uniformity in the quality of the metal upon which the pressures are recorded, as a very much larger number of 'crusher'-cylinders than of 'Rodman'-plates can be produced from one and the same quality of metal."

The crusher-gauge has been in almost daily use since the date of this Report, and from its extreme simplicity, combined with very great accuracy, it has been found to be invaluable.*

When it is not considered desirable to bore holes for the gauges in service guns, the pressure has been obtained at three points—viz. (1) by a crusher in the base of the projectile, (2) by a copper cup, in which a gauge is fastened, at the end of the bore, (3) by inserting a gauge in the vent-bush hole, and firing the gun by electricity, wires being passed down the bore from the muzzle to the cartridge. By this means the pressure is approximately arrived at; but since the copper cup is liable to a certain amount of motion, the record given by the gauge inserted in it is not always reliable. The pressure recorded by the gauge in the base of the projectile, when charges of powder suitable to the calibre of the gun are employed, is always somewhat less than the maximum pressure in the powder-chamber as shown by the other gauges. This is probably due to the fact that the inertia of the shot is overcome, and it therefore begins to move, before the maximum pressure is reached, and, being in motion, the gauge is not influenced to the same extent as those that are immoveably fixed in the walls of the gun.

To give some idea of the pressures recorded by the gauges in a large gun,

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* The following rifled guns have been fitted with these gauges in the manner shown at Plate V.:—9-pr. M.L., 16-pr. M.L., 25-pr. M.L., 40-pr. M.L., 80-pr. M.L., 7-in. B.L. (in vent-piece), 8-in. M.L., 10-in. M.L., 11-in. M.L., 12-in. M.L. (25 tons), 12-in. and 12·5-in. M.L. (38 tons), and 80-ton M.L. in the 14·5-in. calibre, about to be increased gradually to 15 and 16 ins.

the following table is extracted from the Report of the Committee on Explosives on the 38-ton 12·5-in. gun. This gun is bored for crusher-gauges in seventeen places:—A is in the axis of the bore at the breech end; 1 is 1 ft. from the end of the bore; 2 is 2 ft. from the end of the bore; and so on, up to 16, which is 16 ft. from the end of the bore and 6·5 ins. from the muzzle. The regularity with which the pressure decreases as the powder-gas expands—the necessary consequence of the law of expansion of gases—though partially counteracted by the evolution of gas from the unconsumed portion of the charge, which continues to burn until the shot leaves the muzzle, is beautifully exhibited by these experiments.

Table showing the Pressures recorded by the Crusher-Gauges in the Bore of the 12·5-in. (38-ton) Gun.

No. of round.	Charge and projectile.	Pressure in tons per square inch at																	
		A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	On base of shot.
72	130 lbs. of 1·5-in. powder, 800-lb. cylinder	21·5	22·6	22·8	19·2	13·2	9·5	6·3	4·0	2·8	2·9	2·4	2·1	1·4	1·3	1·1	1·0	—	—
138	130 lbs. of 1·7-in. 800-lb. cylinder, with gas-check ...	27·3	26·5	24·5	—	19·3	13·9	8·9	4·8	3·8	3·2	3·1	2·4	1·6	1·4	1·3	1·2	0·7	—
139	130 lbs. of 1·5-in. 800-lb. cylinder, with gas-check ...	26·1	27·7	19·7	—	22·4	11·9	9·4	5·1	4·0	3·1	3·0	2·3	1·7	1·6	1·3	1·3	1·0	21·2
140	130 lbs. of 2-in. 800-lb. cylinder, with gas-check ...	28·7	24·5	22·8	—	18·3	12·4	9·5	4·6	3·2	3·1	2·6	2·3	1·7	1·6	1·3	1·1	0·8	19·3

III.—THE NOBLE CHRONOSCOPE.

This instrument is employed, as before stated, for measuring the time taken by the shot in passing over certain small successive spaces in the bore of the gun, and calculating therefrom the velocity of the shot in passing over each space, and ultimately the mean pressure acting on it through this space. It is the invention of Captain A. Noble, late R.A.—a member of the firm of Sir W. G. Armstrong & Co., in whose works at Elswick the instrument was made.

The following description is taken from the first Progress Report of the Committee on Explosives, dated February 1870, some slight corrections

being made, so as to include the latest improvements in the instrument and in the method of employing it.

The principle of action consists in registering, by means of electric currents upon a recording surface travelling at a uniform and very high speed, the precise instant at which a shot passes certain defined points in the bore.

It consists of two portions—firstly, the *mechanical arrangement* for obtaining the necessary speed and keeping that speed uniform; secondly, the *electrical recording arrangement.* (See Plate V.)

The first part of the instrument consists of a series of thin metal discs, *AA* (Plate V., Fig. 1), each 36 ins. in circumference, fixed at intervals upon a horizontal shaft, *SS*, which is driven at a high speed by a heavy descending weight acting on a chain, *B*—arranged according to a plan originally proposed by Huyghens, through a train of gearing, *F*, multiplying 200 times. The driving weight is, during the experiment, continually wound up by means of the handle, *T*.

If the requisite speed of rotation were got up by the action of the falling weight alone, a considerable waste of time would ensue. To obviate this inconvenience, the required velocity can be obtained with great rapidity by means of the handle, *C*.

The precise rate of the discs is ascertained by means of the stop-clock, *D*, which can, at pleasure, be connected or disconnected with the revolving shaft, *E* (Fig. 1), and the time of making any number of revolutions of this shaft can be recorded with accuracy to the one-tenth part of a second.

The speed usually attained in working the instrument is about 1100 ins. per second linear velocity at the circumference of the revolving discs, so that each inch travelled at that speed represents somewhat less than the one-thousandth part of a second; and as the inch is subdivided by the vernier, *V*, into a thousand parts, a linear representation, at the circumference, is thus obtained of intervals of time as minute as the one-millionth part of a second. As a small variation in speed would affect the relation between the several records obtained, the uniformity of rotation is ascertained on each occasion of experiment by three observations—one immediately before, one during, and one immediately after the experiment—the mean of the three observations being taken for the average speed.

With a little practice, there is no difficulty in arranging the instrument so that the discs may rotate either uniformly, or at a rate very slowly increasing or decreasing.

The *modus operandi* is as follows:—When the requisite speed of rotation has been attained, the stop-clock is connected with the shaft, *E*, and the time occupied by the wheel, *F*, in making five revolutions—that is, the time occupied by the discs, *A*, in making 1000 revolutions—is recorded.

After the wheel, *F*, has made one revolution, unconnected with the clock, the time of making 1000 revolutions is again observed, and in the middle of this observation the gun is fired.

After the wheel, *F*, has again made one revolution, the time of 1000 revolutions is once more recorded, and the instrument is stopped.

An idea of the degree of uniformity realised, when the instrument is in working order, will be furnished by the observations of speed of the instrument for six consecutive rounds, which are given on the opposite page.

CLOCK READINGS.—EXPERIMENTS WITH 38-TON, 12-IN. GUN.

Round No. 14.

			Observed time. secs.
1st observation	1000 revolutions made in	.....	32·0
2nd "	"	.....	31·9
3rd "	"	.....	31·8

Round No. 15.

1st observation	1000 revolutions made in	.....	32·0
2nd "	"	.....	31·9
3rd "	"	.....	31·9

Round No. 16.

1st observation	1000 revolutions made in	.....	31·5
2nd "	"	.....	31·7
3rd "	"	.....	31·6

Round No. 17.

1st observation	1000 revolutions made in	.....	31·5
2nd "	"	.....	31·4
3rd "	"	.....	31·5

Round No. 18.

1st observation	1000 revolutions made in	.....	31·6
2nd "	"	.....	31·6
3rd "	"	.....	31·6

Round No. 19.

1st observation	1000 revolutions made in	.....	32·0
2nd "	"	.....	32·1
3rd "	"	.....	32·2

The maintenance of the speed with so great a degree of uniformity, is obtained by means of very great accuracy of workmanship in all parts of the mechanism.

The arrangements for obtaining the *electrical records* are as follow:—The edges of the revolving discs are covered with smoke by means of an oil lamp, and are connected with one of the secondary wires, *G* (Fig. 1) of an induction coil. The other secondary wire, *H*, carefully insulated, is brought to a discharger, *Y*, opposite the edge of its corresponding disc, and is fixed so as to be just clear of the latter.

When a spark passes from the discharger to the disc, a minute portion of the lamp-black is burnt away upon that part of the disc which was opposite to the discharge at the instant of the passage of the spark. A distinct spot is left on the blackened disc, the lamp-black at that point having been burnt away by the spark, so that the metal is shown beneath.

The mode of connecting the primary wires of the induction coils with the bore of the gun in such a manner that the shot, in passing a defined point,

shall sever the primary current, and thereby produce a spark from the secondary, is shown in Plate VI. Figs. 1, 2, and 3, representing a longitudinal and a transverse section of the bore, *B*, of the gun, along which the shot, *A*, is moving.

A hollow plug, *C*, is screwed into the gun, carrying at the end next the bore a cutter, *D*, which projects slightly into the bore. The cutter is held in this position by the primary wire, *e*, which passes in at one side of the plug, *C*, then through a hole in the cutter, *D*, and out again at the other side of the plug. The two ends of this wire are connected with the main wires leading to the instrument when the plugs have been fixed in this gun.

When the shot, *A*, is fired, it presses the cutter into the second position as shown in the figure, thereby severing the primary wire, and causing the induced spark instantaneously to pass from the discharger to the disc, its passage being marked by the spot left upon the edge, as already described. To prevent a possibility of the cutter being forced down by any gas that may escape past the projectile, a safety-pin, *f*, secures the cutter firmly in its place. This safety-pin is cut simultaneously with the primary wire.

The mode of reading the observations is as follows:—After an experiment has been made, and the series of sparks has been found on the discs, the mark on No. 1 disc is, by means of a micrometer-screw, brought precisely opposite to the point of the discharger; the vernier, *V*, is then attached to the extremity of the shaft, *S*, is firmly fixed there, and is set at zero.

The spark of No. 2 disc is then brought precisely opposite to its discharger, the vernier-reading is recorded, and so with the other discs in succession.

It is obvious that the results furnished by an instrument intended to measure the very small intervals of time necessary for the investigations in which the Committee have been engaged, would be liable to be received with great suspicion, were there no means of testing the accuracy of the instrument; accordingly, one of the chief objects in its design was to arrange that the accuracy of the indications could at any time be tested with facility.

Each disc, discharger, and induction coil, form, so to speak, an independent instrument for recording the spark when the primary wire is broken; and it is obvious that, if the whole of the primaries are cut simultaneously, the sparks on all the discs should be in a straight line, and the deviations from a straight line—that is, from an absolutely simultaneous record—give the instrumental errors.

Great difficulties have, however, been experienced in securing a simultaneous rupture of the primary wires, and the method found most satisfactory has been to connect each circuit with a fine insulated wire, and to wind each of these fine wires tightly round the body of a detonator, containing about 100 grs. of fulminate of mercury. On firing the detonator by electricity, the whole of the wires may be cut nearly simultaneously, and the action of the instrument examined.

The following table shows the mean errors of several consecutive readings of the instrument, the primary wires having been severed in the manner described; and it will be observed how exceedingly slight they are. It is also more than probable that, small as these errors are, they must be in great part ascribed to the impossibility of securing an instantaneous rupture of the currents in all the wires.

Mean Errors.—Simultaneous Observations.

1st *Experiment.*

April 21, 1875.

	secs.		secs.
Disc 1 mean error	·000006	Disc 5 mean error	·000004
" 2 "	·000004	" 6 "	·000002
" 3 "	·000003	" 7 "	·000005
" 4 "	·000002	" 8 "	·000002

2nd *Experiment.*

April 21, 1875.

	secs.		secs.
Disc 1 mean error	·000004	Disc 5 mean error	·000003
" 2 "	·000006	" 6 "	·000005
" 3 "	·000005	" 7 "	·000003
" 4 "	·000007	" 8 "	·000000

April 22, 1875.

	secs.		secs.
Disc 1 mean error	·000004	Disc 5 mean error	·000003
" 2 "	·000004	" 6 "	·000006
" 3 "	·000005	" 7 "	·000006
" 4 "	·000005	" 8 "	·000000

April 28, 1875.

	secs.		secs.
Disc 1 mean error	·000008	Disc 5 mean error	·000002
" 2 "	·000006	" 6 "	·000003
" 3 "	·000004	" 7 "	·000011
" 4 "	·000002	" 8 "	·000003

The errors in none of these observations exceed a few *millionths of a second,* though, as before stated, they include any variation in the time of cutting the wires. The mind is quite incapable of appreciating the minute intervals of time of which we are treating, but the extreme accuracy of the instrument will be apparent when we consider that the one-millionth part of a second is about the same fraction of a whole second as a second is of a fortnight.

The gun shown in Fig. 3, Plate V., is an 18-ton 10-in. rifled M.L. gun, having a length of bore of 145·5 ins.

It was tapped at three places in the powder-chamber, to receive crusher-gauges. These holes could be closed with solid plugs when not required. The cutting plugs belonging to the chronoscope were eighteen in number, and were fitted into holes at various intervals along the bore, as shown in Plate V. When not required for the chronoscope these holes could be used for crusher-gauges, or were closed with solid plugs. The construction of the cutting plugs has been already described. The holes for the cutting plugs at the breech end of the bore were so arranged that the front edge of the projectile was flush with one of them with each of the different charges employed. The projectiles used in these and similar experiments are cast-iron cylinders, having a windage of only 0·01 in.

The loading of the gun is conducted as follows :—

The cartridge is made up to the required diameter; it is then inserted into the shot-chamber, the projectile is next pushed home gently until a stop on the rammer comes into contact with the face of the muzzle. Thus the head of the shot is brought to the same position in each round, and the cartridge always touches the base of the projectile.

The crushers and cutting plugs are then inserted into their respective holes and screwed home.

Finally, the wires of the cutting plugs are connected with the main wires leading to the instrument, and the tube is inserted in the vent.

After the discharge, the first operation is to wash out the gun; all the plugs are then removed and the holes dried preparatory to another round.

The coppers are taken from the crushers, stamped with the number of the round, and the measurements recorded.

The following table, extracted from the Report of the Committee on the 12·5-in. 38-ton gun, shows the velocity of the shot in passing over each foot of the bore from its initial position, and the pressures recorded by the crusher-gauge. Charge, 130 lbs. 1·5-in. cubical powder; projectile, 800 lbs.

No. or letter of plug.	Mean of 4 rounds.			Mean of 3 rounds with gas-checks.		
	Pressure.	Velocity.	Difference in velocity.	Pressure.	Velocity.	Difference in velocity.
	tons per sq. in.	ft.	ft.	tons per sq. in.	ft.	ft.
A	23·8			23·1		
1	23·8			23·6		
2	22·5			22·2		
		137			125	
3	19·9		533	28·0		540
		670			665	
4	14·2		244	16·0		230
		914			895	
5	11·6		127	11·4		130
		1041			1025	
6	7·0		69	6·9		72
		1110			1097	
7	3·8		55	3·9		57
		1165			1154	
8	2·9		47	2·9		49
		1212			1203	
9			40			42
		1252			1245	
10			34			36
		1286			1281	
11			29			31
		1315			1312	
12	1·4		25	1·5		27
		1340			1339	
13	1·6		21	1·7		23
		1361			1362	
14	1·3		18	1·5		20
		1379			1382	
15	1·1		16	1·3		18
		1395			1400	
16	0·6		14	0·5		16
		1409			1416	

The object of the experiments from which the above rounds are taken was to ascertain the gain in velocity obtained by increasing the length of bore of the original 35-ton guns by 36 ins. If it be required to calculate the mean pressure at any point, it is necessary to measure the velocity of the projectile, during the first part of its motion in the bore, over much shorter intervals than a foot. Experiments of this nature were carried out in the 10-in. and 11-in. guns, the distance between the cutter plugs at the seat of the projectile being 0·2 ft. or 2·4 ins., as shown in Plate V., Fig. 3. The following table* gives the data obtained with the chronoscope for calculating velocity and pressure in the bore of the 10-in. gun. Charge, 70 lbs. pebble powder; weight of projectile, 300 lbs.; muzzle velocity, 1527 ft.

Distance from seat of shot.	Time observed at plugs.	Total time from seat of shot.	Time taken by shot to traverse distance between plugs.	Mean velocity over space between plugs.
ft.	secs.	secs.	secs.	ft.
0·00.....	.....	·000000		
			·002683	22
0·06.....	·000000	·002683		
			·001096	183
0·26.....	·001096	·003779		
			·000515	388
0·46.....	·001611	·004294		
			·000356	562
0·66.....	·001967	·004650		
			·000305	656
0·86.....	·002272	·004955		
			·000276	725
1·06.....	·002548	·005231		
			·000488	820
1·46.....	·003036	·005719		
			·000433	924
1·86.....	·003469	·006152		
			·000400	1000
2·26.....	·003869	·006552		
			·000375	1065
2·66.....	·004244	·006927		
			·000703	1138
3·46.....	·004947	·007630		
			·000658	1215
4·26.....	·005605	·008288		
			·000629	1273
5·06.....	·006234	·008917		
			·001192	1342
6·66.....	·007426	·010109		
			·001128	1418
8·26.....	·008554	·011237		

From these data are deduced, by correction and interpolation, the times occupied by the shot in passing over each two-hundredth ($\frac{1}{200}$) of a foot. From the differences of these times are calculated the mean velocities over

* "Researches on Explosives: Fired Gunpowder," by Captain Noble (late R.A.) F.R.S., &c., and F. A. Abel, F.R.S., President C.S., &c. From the "Philosophical Transactions of the Royal Society," Part. I., 1875.

each of these minute spaces, and, from the velocities, the mean pressures necessary to produce them are obtained. These calculations are extremely laborious. The rounds are worked out by Captain Noble (the inventor of the instrument) and an assistant, using two calculating machines, to check one another, and many hours of hard work are required in calculating the pressures for each round. The method of arriving at the velocities, as shown in the foregoing tables, is a comparatively simple matter.

WOOLWICH,
10th January, 1876.

Fig. 1. Chronograph in position for measuring the velocity of projectiles.

Scale $\frac{1}{8}$th "

Side view from the left. *Front view.*

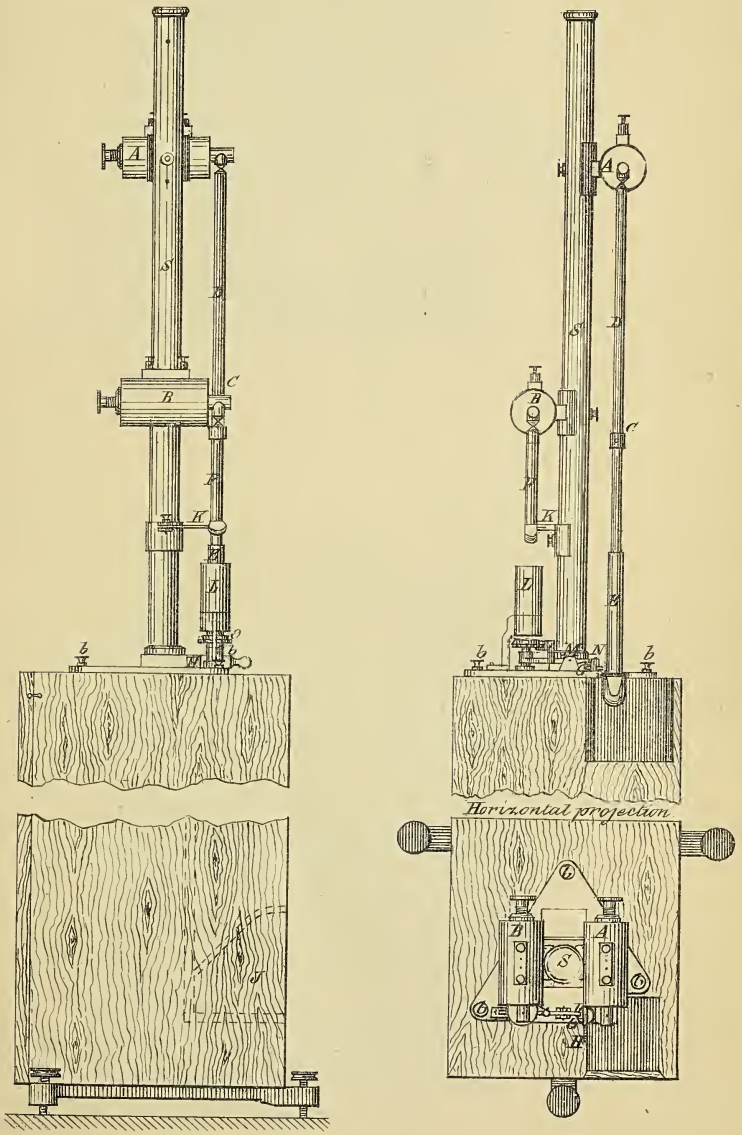
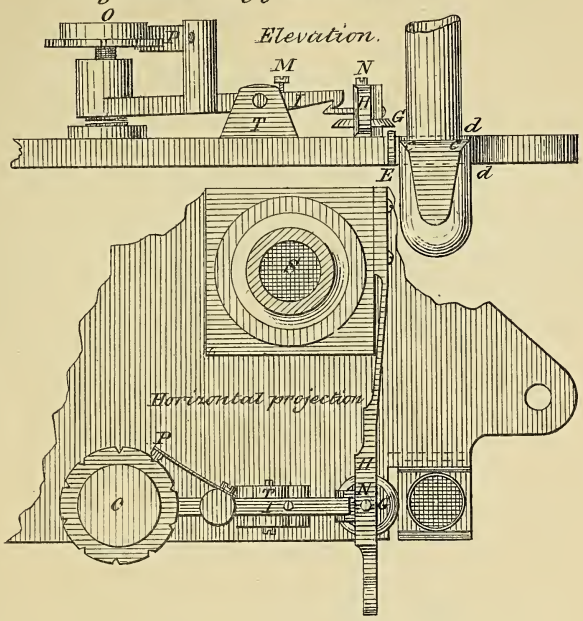


Fig 7. The Trigger. (Scale $\frac{1}{2}$.)



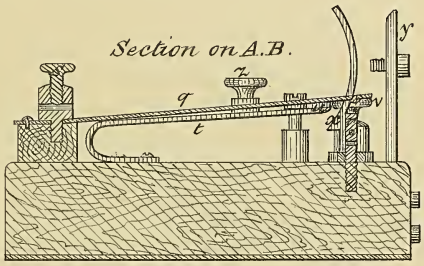
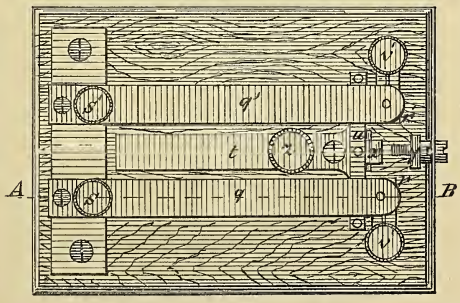
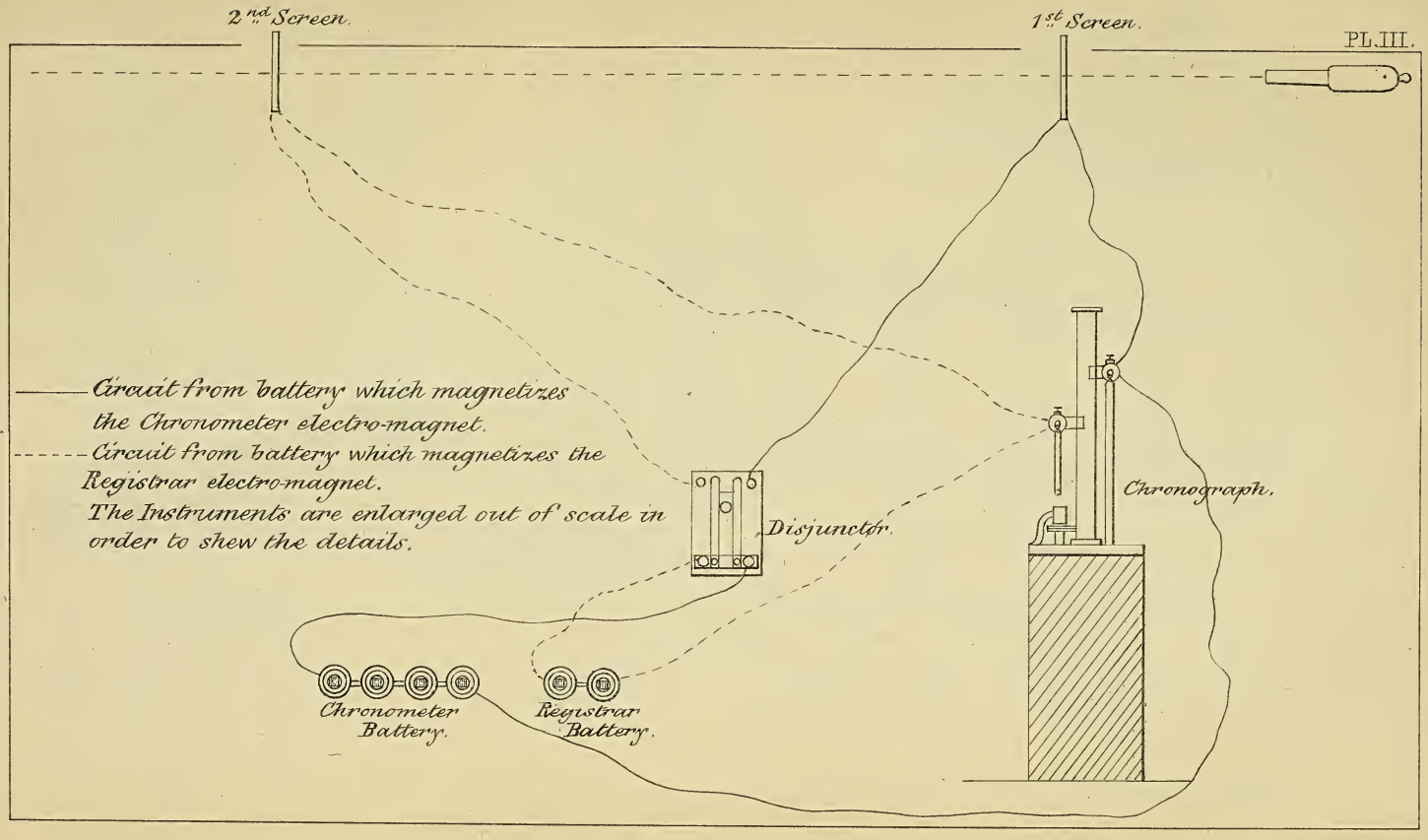


Fig 9. Disjunctor. (Scale $\frac{1}{2}$.)

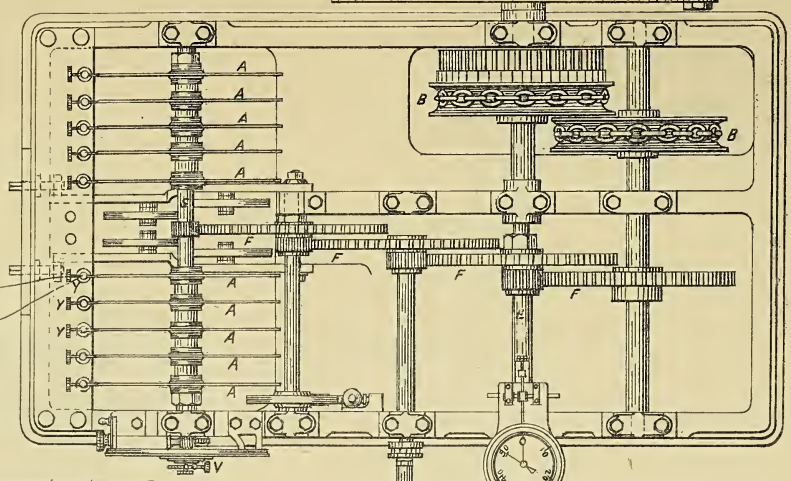


Horizontal Projection.


2nd Screen.
1st Screen.
Circuit from battery which magnetizes the Chronometer electro-magnet.
Circuit from battery which magnetizes the Registrar electro-magnet.
The Instruments are enlarged out of scale in order to shew the details.
Disjunctor.
Chronograph.
Chronometer Battery.
Registrar Battery.

SCALE. INSTRUMENT ABOUT $\frac{1}{12}$TH
GUN ABOUT $\frac{1}{36}$TH

FIG. 1.



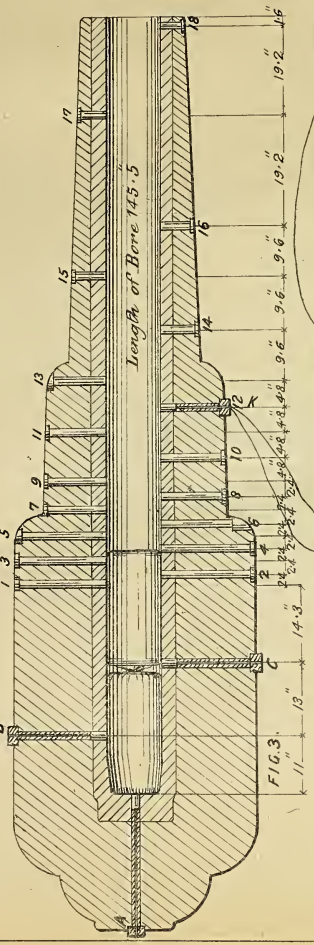
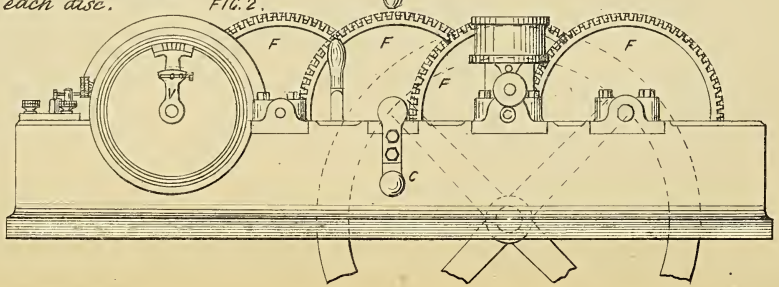


FIG. 3.

NOTE. To avoid Complication only one Induction Coil and Cell is shewn, a Cell and Coil being required for each disc.

FIG. 2.



CUTTING PLUGS.

Scale $\frac{1}{2}$.

FIG 2.

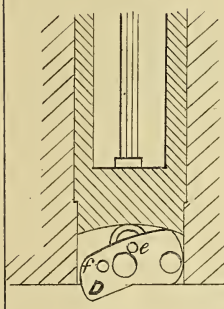
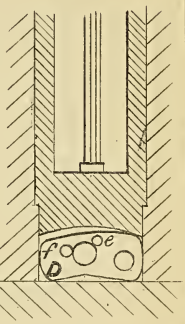


FIG 1.



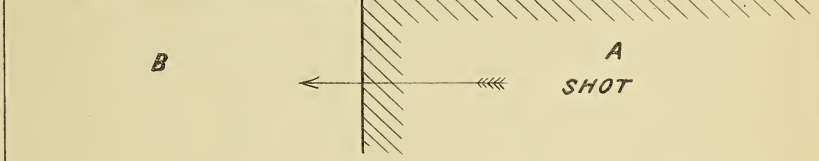
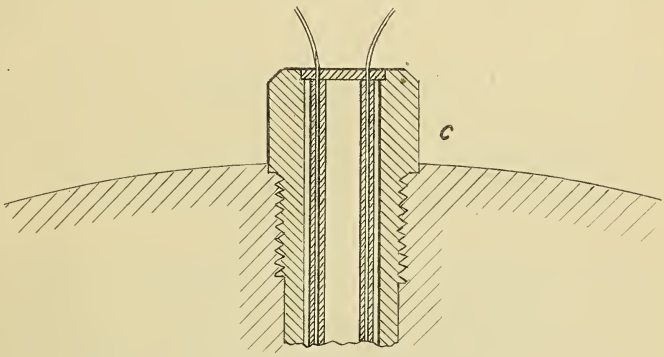
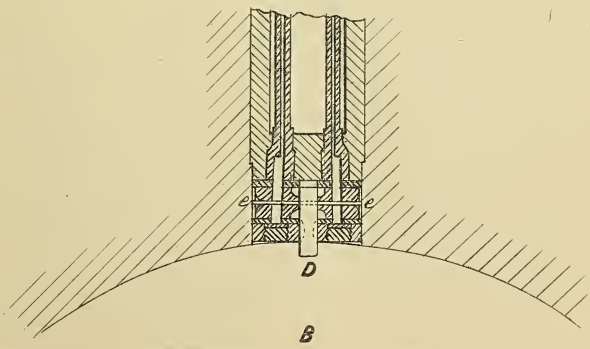


FIG 3.





RECENT HISTORICAL NOTES

CONNECTED WITH THE

ROYAL REGIMENT OF ARTILLERY.

[No. I.]

E. T. MICHELL.

THE following notice of a distinguished artillery officer having been found among the papers of the late Colonel Colquhoun, R.A., is communicated to the Secretary of the Royal Artillery Institution, by Major F. Duncan, R.A., for publication in the "Proceedings" at a time when attention has been again called to the Eastern relations of England. By a memorandum which accompanied the MS. it appears that the main facts were communicated in 1844 to the "Naval and Military Gazette," but they are probably new to most of the officers now serving in the corps.

MEMORIAL AT JAFFA

TO THE LATE

BRIGADIER-GENERAL E. T. MICHELL,

ROYAL ARTILLERY.

"On the death of Brigadier-General E. T. Michell, which took place at Jaffa in Jan. 1841, at the close of the operations that terminated in the evacuation of Syria by the Egyptians, the officers of the staff and detachments who had served under his orders resolved to consecrate to his memory, in the Bastion of Sir Sydney Smith, at Jaffa—where his remains were interred—a testimony of their esteem and of their deep regret. To carry into effect their intention, it was, however, necessary to obtain permission from Constantinople—the tomb being enclosed within the walls of a Turkish fortress. This caused some delay; but by the kindness of Sir Stratford Canning, H.M.'s Ambassador at the Porte, the necessary authority was at length procured. The grave is in the left flank of the bastion, overshadowed by a fig tree, and opposite (on the interior face of the parapet in front of it) is placed a tablet of white marble of large dimensions, bearing the following inscription, preceded by two lines of Arabic poetry. The object of the latter is to claim from everyone—whatever their creed, Christian, Moslem, or Druse—the respect that is due to the distinguished dead. They may be thus translated:—

"'This narrow grave contains the remains of one whose fame during life was widely extended. Let all respect it, for he was of those who have rendered their period illustrious.'

"The English inscription is as follows:—

'Sacred to the Memory of

RRIGADIER-GENERAL EDWARD THOMAS MICHELL,

OF THE ROYAL ARTILLERY,

COMMANDING THE FORCES OF HER BRITANNIC MAJESTY IN SYRIA,

COMPANION OF THE ORDER OF THE BATH,

COMMANDER OF ISABELLA THE CATHOLIC,

AND KNIGHT OF ST. FERDINAND AND OF CHARLES III. OF SPAIN,

WHO DIED AT JAFFA ON THE 24TH OF JANUARY, 1841,

AET. 54.

HE WAS DISTINGUISHED BY HIGH AND NOBLE QUALITIES,

BY LONG AND BRILLIANT SERVICES,

AND BY THE AFFECTIONATE REGARD OF ALL WHO KNEW HIM.

THE OFFICERS OF H.B. MAJESTY'S FORCES SERVING IN SYRIA,

IN TESTIMONY OF THEIR ESTEEM AND REGRET,

AND TO RENDER SACRED THE SPOT WHERE HIS REMAINS REPOSE,

HAVE ERECTED THIS STONE TO HIS MEMORY.'

"In conformity with the Vizierial letter obtained by the Ambassador, satisfactory directions were given by Assaad Pasha, the Turkish Commander-in-Chief in Syria, to the Governor of Jaffa, and on the arrival of the monument from Malta, the erection of it was at once proceeded with. Mr. Young, Her Majesty's Consul at Jerusalem, had been requested by Colonel Rose* to afford any aid that might be required, but this was not needed; for on the 18th May he wrote to Col. Rose:—

Mr. Young to Col. Rose.

"'I have the satisfaction to inform you that the Vice-Consul, with the aid of Captain Glascock and several of the officers and men of the Tyne, had already accomplished the undertaking before my arrival; and you will be gratified to learn that the Governor of the town of Jaffa took an interest in the proceedings, and lent his good offices towards the fulfilment of this last duty, so eminently due to the distinguished individual whose death his brother officers commemorate in the erection of the tablet.'"

It is not often that the Turk joins to do honour to the grave of a Christian; but it is due to those of Syria to say that the tomb of Major Oldfield, of the Marines, who fell in the defence of Acre, under Sir Sydney Smith, in 1799—*placed in a public thoroughfare of the fortress*—was found in 1840 to be perfect, and free from any defacement; seeming to prove that in the profession of arms, or the fellowship of those who have fought together, there is something that is capable of mitigating even the intolerance of hostile creeds.

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* Now Lord Strathnairn.

The following correspondence passed between Colonel Rose and Captain Glascock, R.N. :—

"BEYROUT, MAY 21, 1844.

"SIR,

"On the part of the officers of Her Majesty's army serving under the orders of the late Brig.-General Michell, of the Royal Artillery, I beg to return you my grateful acknowledgements for the kind and efficient aid given by yourself, your officers, and men, in the erection of a monument to the memory of that gallant officer in the bastion called Sir Sydney Smith's, at Jaffa. It was our wish to record—*not* the merits of the deceased (for they belong to history), but our lasting remembrance of one whose heart was as amiable as it was resolute, and whose talent and courage made him conspicuous even amongst the scientific and chivalrous corps to which he belonged. That the last tribute of his brother officers' esteem should have been placed over his remains by officers and men of Her Majesty's navy, is an additional source of honour to his memory and of consolation to those who cherish it.

"I have, &c. &c.,

"HUGH ROSE.

"Capt. Glascock, R.N.,
"H.M.S. Tyne."

Reply.

"H.M.S. TYNE, BEYROUT,
"May 21, 1844.

"SIR,

"I have to acknowledge the receipt of your letter of this day's date, relative to the transit and erection of the monument now to be seen at Jaffa, over the grave of the late Brigadier-General Michell. The handsome manner in which you have conveyed to me your acknowledgements for the performance of a task which the officers and seamen under my command had regarded only in the light of the diligent discharge of a sacred duty, due to the memory of a gallant, meritorious, and well-beloved officer, is, I can assure you, fully appreciated; and I shall not fail to read publicly to those who have been employed on the service in question the entire contents of your complimentary letter.

"I have, &c.,

"WM. MIGT. GLASCOCK.

"Colonel H. Rose, C.B.,
"Consul-General of H.B. Majesty,
"Beyrout."

The following extract (on the same subject) from a letter, signed F. Robe, dated 24th January, 1841, is a pleasing memorial :—

"The immediate cause of the General's sudden dissolution has not been ascertained; but it is conjectured that some vessels injured by effects of former wounds have given way, and that his frame was too enfeebled to rally. Poor fellow! he has died as he lived, a thorough soldier, and one of the brightest ornaments of your distinguished corps. Few men have left this world more sincerely regretted than will be poor Edward Michell, ... and few better prepared to render account of their actions on earth."

Another extract from a letter of a brother officer to a friend in Jerusalem, dated Jaffa, 28th January, 1841, summarises the prominent features of General Michell's character:—

"There never was a better soldier than Edward Michell, and few better men. As a public servant, and in loyalty, moderation, and gentleness of character, he was a model to all. Just and considerate to all below him, and inspiring confidence by his talent, his disinterestedness, and his sense of duty, he commanded the good-will of all. He was at the same time remarkably energetic in character; a quality which in him was produced by a clear perception of circumstances—of results that were possible and useful, and of the just and proper means to be employed to attain them. God rest him! There are many that will weep for him, for he was beloved by everyone that knew him, and all will cherish his memory. To me his death creates a void that can never be filled. . . . . He was also illustrious by his services."

N.B.—The war services of General Michell may be stated briefly as follows:—

"Commanded a guerilla division in 1810 in the Sierra de Ronda; was present at the capture of Ronda, combats of El Brosque and of Bornos, and night attack and capture of Arcos. Commanded the artillery with the force occupying Tarifa in 1810–11–12, and was engaged in all the affairs and operations at Terifa, Vejer, Casas Viejas, Alcalà, Medina Sidonia, and the battle of Barossa. He is specially mentioned by Napier for his skilful handling of the artillery at the final defence of Tarifa in December 1811. In 1812 he was present at the capture of the Salamanca forts, the battle of Salamanca, and the combat of Castrejon. He served in the Netherlands from December 1813 to May 1814, at the capture of Merxem, bombardment of Antwerp, and night attack on Bergen-op-Zoom. He distinguished himself several times—on one occasion extracting the fuze of a live shell which had fallen into an ammunition wagon. He conducted a column in the assault on Bergen-op-Zoom, and was severely wounded. He served as British Commissioner with the Spanish armies from August 1839 to November 1840. In November 1840 he was appointed, as Brigadier-General, to the command of the British forces in Syria, and was present at the action of Medjdel on the 15th January 1841. (*Vide* "Kane's List.")

ON

THE HEAVY 4-PR. GUN FOR FIELD BATTERIES,

PROPOSED BY THE RUSSIAN ARTILLERY COMMITTEE.

BY

CAPTAIN PASKEVITCH.

(From the "Russian Artillery Journal" for July 1875).

Translated into Italian, and published in the "Giornale d'Artiglieria e Genio" for October 1875, and thence translated by

COLONEL H. H. MAXWELL, R.A.

The Russian field artillery is armed with guns of fair accuracy and remarkable explosive effect. The only desirable improvement in the system of field guns is a greater probability of a hit at long ranges and a flatter trajectory, so as to reduce to a minimum the effect of an incorrect estimate of the distance on the precision of fire.

In Russia, since 1866, the question of attaining flatter trajectories for the field guns has been agitated. Now, an increase of the tension of the trajectory can only be obtained by an increase of the initial velocity of the projectile. Therewith, the accuracy of fire increases in a high ratio, provided that the construction of the piece satisfies essential conditions. But if we increase the initial velocity of the projectile, we are met by the following difficulties—an increase of strain on the carriage, of recoil, and of gas-pressure in the bore in firing. It is therefore necessary, if the relative charges of the field guns are to be increased, either to diminish the calibre or to increase the weight of the piece. A diminution of calibre is limited by the necessity of adequate explosive effect in the projectile; besides, if we diminish the calibre to any great extent, we lose notably in flatness of trajectory and in accuracy of practice at long ranges. An increase in the weight, again, is limited by the necessity of keeping the weight of the gun riding on its carriage within a moderate figure, and of carrying an adequate supply of ammunition with the piece.

Seeing the advantages obtainable by an increase of initial velocity, experiments were made in 1867, after the introduction of the rifled B.L. bronze guns by the Russian artillery, with a bronze 4-pr. gun (calibre 4·213 ins.), firing lead-coated elongated common shells of 14 lbs. weight (12·65 lbs. Eng.) and a charge of one-fourth of the weight of the projectile. The weight of the piece was fixed at 38 pud (12½ cwts.)—that is, equal in weight to the existing 9-pr. (calibre 4·2 ins.); the

length of bore was 21 calibres. The weight and length of the piece were thus laid down with the intention—1st, of diminishing as far as might be the strain on the carriage, and 2nd, of utilising as far as possible the action of the heavy charge on the projectile. With the above data and a pitch of rifling of 1 turn in 60 calibres, a velocity of 1340 ft. per second was attained. The following are the results of the experiments:—

Distance.		Angle of elevation.	Angle of incidence.	Mean quadratic deviation.	
				Vertical.	Lateral.
sagènes.	yds.	° ′	° ′	yds.	yds.
500	1167	2 25	2 45	0·66	0·93
1000	2333	5 40	7 8	2·54	2·40
1500	3500	9 55	13 57	10·43	4·27

Comparing these results with the analogous data of the Russian service field guns, we see that a great increase in accuracy and in flatness of trajectory was obtained.

With the service 4-pr. and 9-pr., which fire with a gun-charge of one-ninth of the weight of the projectile, giving an initial velocity of 1004 and 1060 ft. per second respectively, the following are the results of practice:—

Gun.	Distance.		Angle of elevation.	Angle of incidence.	Mean quadratic deviation.	
					Vertical.	Lateral.
	sagènes.	yds.	° ′	° ′	yds.	yds.
4-pr.	500	1167	3 20	3 48	1·40	1·03
	1000	2333	7 39	9 45	5·44	3·31
	1500	3500	12 32	18 59	22·44	6·93
9-pr.	500	1167	2 57	3 24	1·03	0·86
	1000	2333	6 52	8 26	4·20	2·36
	1500	3500	11 43	15 36	13·15	4·90

Determining from these data* the probability of a direct hit on a vertical target 6 ft. high by a length of 25 paces (58 ft.) we find:—

* To compare the accuracy of fire, we do not take the mean quadratic deviations in *length*, as they principally depend on the angle of incidence; but seek the *vertical* deviations, which, though dependent on the inclination of the trajectory to the horizon, are much less affected by the angle of descent than the longitudinal deviations, in consequence of the great tension of the trajectory. In the case where it is intended to compare the results of high-angle fire, we should compare the longitudinal deviations with each other, and not those obtainable on a vertical target.—*Author's note.*

Number of Hits per cent. on a Target 6 ft. × 58 ft.

Distance.		Guns.		
		4-pr. V = 1004 f.s.	9-pr. V = 1060 f.s.	4-pr. V = 1340 f.s.
sagènes.	yds.			
500	1167	52	66	87
1000	2333	16	18	31
1500	3500	3	5	8

From these tables it appears that by increasing the initial velocity of the 4-pr. common shell to 1340 ft. per second, the trajectory is from 10 per cent. to 19 per cent.—according to the distance—flatter than that of the 9-pr. (weight of shell filled, 24¼ lbs.) fired at a velocity of 1060 ft. per second, and 26 per cent. flatter than that of the 4-pr. common shell fired with an initial velocity of 1004 ft. per second.

Further, the probability of a hit on a vertical target at a distance of 500 sagènes (1167 yds.) is in excess of that of the 9-pr. by 33 per cent. and of the ordinary 4-pr. by 67 per cent.

Although at a range of 1500 sagènes (3500 yds.) the probability of a hit with the 4-pr. common shell, with an initial velocity of 1340 ft. per second, exceeds considerably the probability of a hit with the service field guns, still that probability is so small that with the heavy 4-pr. it would be wrong to open fire at such a distance excepting in rare cases.

To form an idea of the gain in the probability of a hit, let it be agreed that the maximum distance at which we should open fire is that at which one-fourth of the shots would strike a target 6 ft. × 58 ft.; we shall then find that this distance with the present 4-pr. is 800 sagènes (1867 yds.), with the present 9-pr. 900 sagènes (2100 yds.), and with the heavy experimental 4-pr., with an initial velocity of 1340 ft. per second, it is 1100 sagènes (2567 yds.)

In 1870, intelligence having been received of the experiments with a heavy steel 4-pr. by the Prussian artillery, a steel 4-pr. gun was designed in Russia to fire at an initial velocity of 1700 ft. per second. The length of the bore and the weight of the piece were approximately identical with those of the heavy bronze experimental gun; but in order that the gun should resist with safety the strain of firing a charge sufficient to give the projectile so high a velocity, it was hooped with steel rings at the breech. Furthermore to diminish the expansive action of the charge, it was decided to use large-grain powder (0·25-in. to 0·4-in.) of a density of 1·72. The experimental guns were made in the Obuchoff and Perm gun foundries. With a projectile weighing 14 lbs. (12·65 lbs. Eng.) inclusive of the lead-coating, and with a gun-charge of 5½ lbs. (4·69 lbs. Eng.)* of powder, the initial velocity was 1703 ft. per second. With this charge, a pitch of rifling of 1 turn in

* Relative charge = $\frac{1}{2.5}$ nearly.

70 calibres was found most suitable. The following were the results obtained:—

Distance.		Angle of elevation.	Angle of incidence.	Mean quadratic deviation.	
				Vertical.	Lateral.
sagènes.	yds.	° ′	° ′	yds.	yds.
500	1167	1 36	2 3	0·93	1·07
1000	2333	4 18	6 12	3·06	3·03
1500	3500	8 7	12 26	7·85	6·50

These results prove that the accuracy of the hooped steel 4-pr. is very closely the same as that of the bronze gun firing at an initial velocity of 1340 ft. per second, and that the tension of the trajectory is from 20 per cent. to 40 per cent. greater than that of the 9-pr. service gun.

The cause of there being no increase of accuracy, despite the increase of initial velocity from 1340 to 1703 ft. per second, is due probably to the injury suffered by the lead-coating of the projectile from the high velocity. It would appear that what ought to have been gained in accuracy through increase of velocity was lost by the perturbation of the motion of the projectile as it passed along the bore of the gun, due to the damage done to the lead-coating.

The better to appreciate the influence of the tension of the trajectory and of the accuracy of fire on the probability of a hit with the heavy steel 4-pr. as compared with the service 4 and 9-prs., let us calculate the probabilities in firing at low angles, both when the distance is accurately known and when an error is made in estimating it. The result of these calculations is contained in the following table:—

Number of Hits per cent. on a Target 6 ft. × 58 ft.

Distance.		Firing at distances accurately known.		Firing at distances wrongly estimated			
				by 2 per cent.		by 5 per cent.	
		Heavy 4-pr.	Service 9-pr.	Heavy 4-pr.	Service 9-pr.	Heavy 4-pr.	Service 9-pr.
sagènes.	yds.						
300	700	95	95	92	86	73	37
400	933	82	82	72	58	33	1
500	1167	68	67	52	34	11	1
600	1400	56	53	36	20	8	—
700	1633	46	41	25	13	—	—
800	1867	38	31	17	9	—	—

As will be seen from this table, there is no substantial difference between the two guns thus compared, so long as the distances are

either short, medium, or accurately known; but when fire is opened at incorrectly-judged distances, the probability of a hit is quite another thing. We can see from the table, admitting an error in estimating the distance of 2 per cent., that we may fire the heavy 4-pr. at 700 sagènes (1633 yds.) and the 9-pr. at 550 sagènes (1283 yds.) with the like good results, as at these distances 25 per cent. of the shots would strike the target. With an error of 5 per cent. in the estimate of the distance, the probability of striking the target from either gun, even at short and medium ranges, is very small. If we compare the distances at which one-fourth of the projectiles fired would strike the target, we find—admitting an error of 5 per cent. in the estimate of the distance as before—that for the heavy 4-pr. the range would be 450 sagènes (1050 yds.) and for the 9-pr. 330 sagènes (770 yds.)

Although accuracy of fire and tension of trajectory constitute most important elements in the effect of fire in a field gun, its projectile should also possess considerable and accurate explosive effect. In the present state of the technical arts, the only method of increasing the explosive effect is that of increasing the calibre and weight of the piece.* But therewith the difficulty of handling the piece, of the transport of a sufficient number of rounds, and of covering the piece from the enemy's fire, inevitably increases. It is very probable that by increasing the rate of firing a satisfactory increase in the explosive effect produced by field guns is attainable, thus avoiding the difficulties incident to an increase of calibre; but proof that the question can be solved in this manner is not forthcoming. Moreover, as the steel and bronze experimental 4-prs., which fire at high initial velocity, weigh about the same as the 9-pr., whilst the filled projectiles of the former weigh about one-half that of the latter, it is obvious that the 4-prs. must be inferior to the 9-pr. in explosive effect. For these reasons, the experiments with a 4-pr. of a weight equal to the 9-pr. were abandoned in Russia. Seeing, however, the utility of increasing the initial velocity of the projectile with reference to precision of fire, and that new field guns firing at high velocities are being introduced by many foreign powers, the Russian Artillery Committee proposed a heavy field gun weighing 30 pud (9 cwts. 2 qrs. 18 lbs.), for firing at high velocity. A drawing of the gun and projectile are appended. (See drawing).

In order that the new experimental gun should have a clear advantage over the present field guns as regards accuracy of fire and tension of trajectory, the projectile must have an initial velocity of not less than 1500 ft. per second; and not to sacrifice aught in explosive effect, the common shell must weigh not less than 14 lbs. (12·65 lbs. Eng.) With these data, the new field gun, riding on the service carriage, would not be subject to a greater strain than the service gun. In order to diminish the expansive force of the gas of the charge, it is proposed to use large-grain gunpowder, similar to that fired in the steel 4-pr.; and in order to increase the power of resistance of the heavy bronze gun, it is intended to cast it in a metal mould and to compress the metal in

* ? watershell.—*Eng. Tr.*

its liquid state; further, after the gun has been bored to a calibre slightly below the finished dimensions, to drift it with wedges slightly larger than the then diameter—thus subjecting it to internal pressure; and finally to bore up and rifle the gun. A few heavy 4-prs. of this pattern have been made—some with a regular twist of different pitches (from 1 turn in 50 to 1 turn in 60 calibres), others with an increasing twist.

Rifling with a progressive twist presents the advantage of giving a small inclination to the grooves, with reference to the axis of the piece, in that part of the gun where the pressure of the gas is at its greatest; so that the driving sides of the grooves incur little danger of injury. As the projectile, however, approaches the muzzle, the inclination of the grooves increases with the velocity of translation; and thus, without danger to the driving sides of the grooves, it appears possible to attain a considerable velocity of rotation, and thereby to increase the precision of fire.

In the experimental 4-pr. gun, the inclination of the increasing twist of rifling at the muzzle corresponds to a pitch of 1 turn in 45 calibres. The projectiles for this piece have a thicker base to the common shell than the service shells, to avoid the danger of a burst in the bore. Some of the common shells for the guns rifled with a regular twist are coated with a hard alloy, and others have rings of copper wire (*sic*). The part of the shell intended to take the rifling is of an alloy harder than lead, to prevent stripping and irregularity of motion in the bore. By this means increased precision of fire is aimed at. With the gun rifled with an increasing twist, it is intended to use projectiles with copper rings. One of the latter is—as may be seen in the drawing—near the base of the projectile, and takes the grooves in firing. At the point of junction of the ogive and cylinder of the shell is a second ring, of a diameter somewhat less than that between the lands of the gun. This ring is intended to steady the shell in the bore.

Besides the ordinary common shells with solid walls, it is intended to try double-walled shells. In these shells—as may be seen in the drawing—the walls are formed of two concentric strata, each of which is formed into a series of pyramids with blunt apices.*

This method of construction is intended to increase the number and uniformity of the fragments in bursting. If it be found that these shells are not inferior to ordinary shells in their effect against masonry, it would be advisable to adopt them in supersession of the old pattern.

The heavy bronze 4-pr. is intended for the armament of the field batteries, which however would partially retain the present 9-pr. The horse artillery would still be armed with the present 4-pr. gun of 20 pud (6·45 cwts.); an extremely light piece—light beyond comparison with the heavy 4-pr.—and exactly realising the main essentials of a gun intended to accompany cavalry.

Let us now compare the service field guns of foreign powers with the Russian artillery, inclusive of the new gun. In two of the following tables will be found numerical data regarding the construction of the guns and projectiles, while the third will give some idea of their effect:—

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* As seen in a longitudinal section. Each pyramid is a triangle.—*Eng. Tr.*

Guns.

Description of guns.		Calibre.	Weight. in	Weight. in projectiles.	Ratio of weight of charge to projectile.	Initial velocity.	Pitch of rifling, 1 turn in
		ins.	lbs.			f.s.	cals.
Austria	4-pr. B.L.	3·425	9·59	76	0·23, $\frac{1}{4}$	1552	45
	8-pr. M.L.	3·976	10·83	75	$\frac{1}{7}$	1125	21
England	9-pr. M.L., light	3	6	74	0·19, $\frac{1}{5}$	1391	30
	" " heavy	3	8·25	105	0·19, $\frac{1}{5}$	1380	30
	16-pr. "	3·6	12·10	88	0·19, $\frac{1}{5}$	1355	30
	25-pr. " position	4	—	97	0·18, $\frac{1}{5}$	—	—
Germany	8c B.L. for H.A.	3·08	7·68	77	0·24, $\frac{1}{4}$	1522	51
	9c " " F.A.	3·465	8·86	64	0·21, $\frac{1}{5}$	1460	51
Italy	7c B.L.	2·953	5·8	83	0·15, $\frac{1}{6}$	1312	46·7
Russia	4-pr. light B.L. for H.A.	3·42	6·77	60	0·11, $\frac{1}{9}$	997*	41
	" heavy " " F.A.	3·42	9·66	83	about $\frac{1}{4}$	1589	abt 50
	9-pr. B.L. for F.A.	4·2	12·24	56	0·11, $\frac{1}{9}$	1092	50
France	5k B.L.	2·953	9·35	99	0·18, $\frac{1}{6}$	1348	30
	7k "	3·347	12·8	93	0·16, $\frac{1}{6}$	1280	21
Switzerland	8c B.L.	3·307	8·52	78	0·15, $\frac{1}{6}$	1299	39
	10c "	4·134	12·52	81	0·13, $\frac{1}{8}$	1305	39

Projectiles.

		Common shell. Weight. Total.	Common shell. Weight. Per sq. in. of cross section.	Common shell. Ratio of weight of projectile to burster.	Common shell. No. of fragments above 2·2 ozs. in weight.	Shrapnel shell. Weight.	Shrapnel shell. Weight of burster.	Shrapnel shell. Number of bullets.	Shrapnel shell. Weight of one bullet.
		lbs.		1 to		lbs.	ozs.		
Austria	4-pr.	13·97	1·52	33	60	—	—	—	—
	8-pr.	14·48	1·25	15	60	16·39	4·2	140	0·46
England	9-pr.	9·06	1·33	19	36	9·80	0·75	63 { 28, 35	0·88, 1·23
	16-pr.	15·81	1·98	16	—	16·31	1·5	119 { 63, 56	0·88, 1·23
	25-pr.	—	—	—	—	—	—	—	—
Germany	8c	11·15	1·98	26	30†	12·17	6·7	122	—
	9c	15·40	1·65	25	35†	17·43	7·9	209	—
Italy	7c	8·28	1·11	19	—	9·22	0·4	100	0·58
Russia	4-pr., light	12·63	1·38	28	25	14·43	3·6	105	0·42
	" heavy	13·18	1·42	28	abt 50	13·18	2·3	150	0·42
	9-pr.	24·35	1·76	27	30	29·88	7·2	210	0·42
France	5k	10·56	1·44	23	—	—	—	—	—
	7k	15·4	1·70	20	54	—	—	—	—
Switzerland	8c	12·21	1·42	16	36	12·34	0·7	130 { 105, 25	0·77, 0·58
	10c	17·27	1·24	13	—	20·35	0·7	170	0·58

* Let the reader judge how far the eulogium passed on this gun is deserved after considering the bearing of this figure. The main essential of a gun is to hit hard. It admits of a doubt whether this gun can.—*Eng. Tr.*

† At p. 2 of an article translated from the "Revue Militaire de l'Etranger," published in R.A. Institution "Translations," No. 1 Vol. IX., it is stated, with regard to the new German guns,

Practice.

Calibre.	Distance.	Angle of incidence.	Mean quadratic deviation. Vertical.	Mean quadratic deviation. Lateral.
	yds.	° ′	yds.	yds.
Austria. 4-pr.	1167	—	0·86	0·59
	2333	—	2·19	2·40
	3500	—	3·72	4·40
Austria. 8-pr.	1167	—	—	—
	2333	11 25	7·00	4·23
	3500	23 2	21·84	10·06
England. 9-pr.	1167	2 11	1·06	—
	2333	8 49	3·56	2·72
	3500	17 36	10·90	4·77
England. 16-pr.	1167	—	0·49	0·63
	2333	6 24	2·70	1·60
	3500	14 9	5·83	2·77
France. 8^c ...	1167	2 24	1·26	1·37
	2333	6 2	4·06	3·67
	3500	11 19	13·33	6·67
France. 9^c ...	1167	2 33	1·14	1·14
	2333	6 19	4·43	3·14
	3500	11 12	11·07	6·04
Russia. 4-pr. light	1167	3 48	1·40	1·47
	2333	9 45	5·43	3·06
	3500	18 59	22·50	6·84
Russia. 4-pr. heavy (expl.)	1167	2 24	*	
	2333	6 40		
	3500	13 12		
Russia. 9-pr.	1167	3 24	1·03	0·86
	2333	8 26	4·20	2·36
	3500	15 36	13·36	4·90
France, 7^k	1167	2 38	1·33	1·81
	2333	7 12	3·40	2·67
	3500	13 42	8·60	4·83
Switzerland. 8^c	1167	—	0·63	0·73
	2333	7 35	2·60	2·20
	3500	15 0	7·86	4·23
Switzerland. 18^c	1167	—	0·63	0·73
	2333	—	2·60	1·94
	3500	17 45	7·86	3·60

From this table it will be seen that in Russia the two calibres of the field artillery differ from each other more than in any other country (excepting in England, where a gun of position has been adopted). In some states, on the other hand—in Germany for example—two calibres have been adopted differing from each other so little that it is difficult to understand how their co-existence is justifiable.

Despite the fact that the calibre of the 9-pr. gun is larger than that of any of the foreign guns, its weight is not excessive; it is a little less than the 7^k French and the 10^c Swiss gun, and much less than the English 25-pr. gun of position.

The weight of the light Russian 4-pr. exceeds that of the 7^c Italian

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that at 1500 metres (1640 yds.), firing at targets with double-sided shells, the light gun (German 8^c) gave a mean of 60 hits per round, and the heavy gun (9^c) 90 hits per round. *If* the figures in the above table and this quotation be true, many of the hits of the "Revue Militaire" must have been made with small fragments, a good many of which may have been ineffective.—*Eng. Tr.*

* Experiments not having been made with this piece, its shooting may be taken as equal to that of the Austrian 4-pr.—*Author's note.*

Note by Editor of the "Giornale d'Artiglieria e Genio."—Without discussing the accuracy of the data contained in the above table, we may observe that the following are the results of practice with the $7{\cdot}5^c$ Italian gun:—

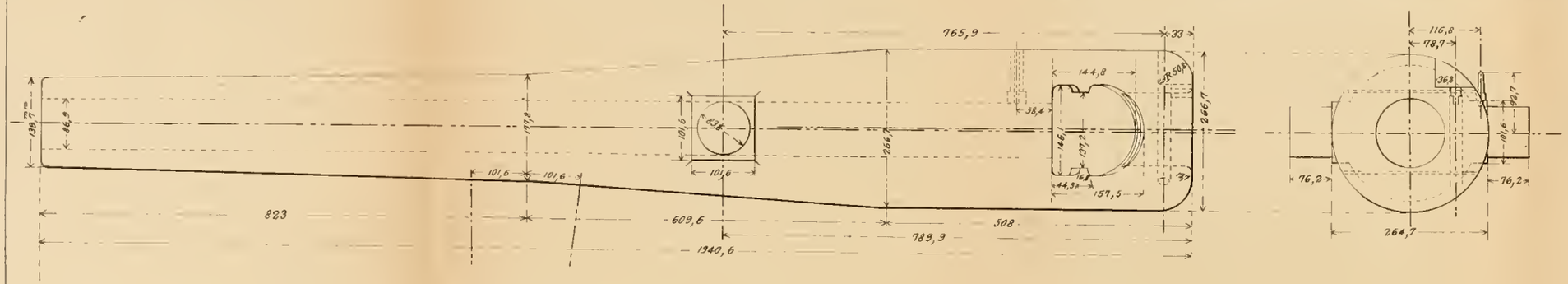
Distance.	Angle of incidence.	Mean quadratic deviation. Vertical.	Mean quadratic deviation. Lateral.
yds.	° ′	yds.	yds.
1167	3 18	0·85	—
2333	8 49	3·81	—
3500	16 45	10·45	—

DESIGN FOR A NEW RUSSIAN FIELD GUN.

HEAVY BRONZE 4 Pr. GUN.

Scale of $\frac{1}{8}$.

Dimensions in Millimetres 1 mm = 0·3937 Eng.



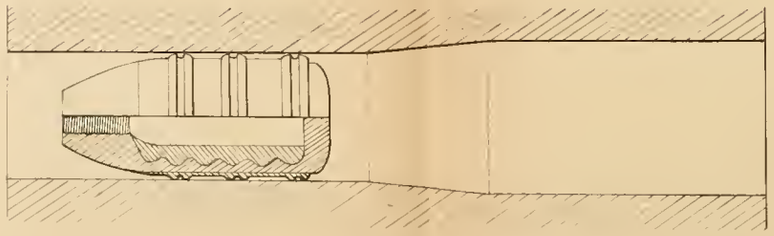
RIFLING OF REGULAR TWIST

At the muzzle — *At the origin at the breech*

Scale of $\frac{1}{1}$.

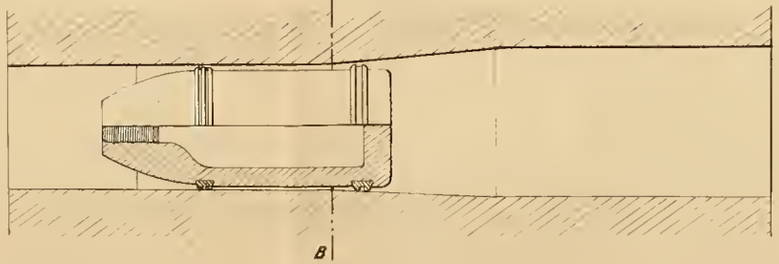
CHAMBER OF REGULAR TWIST OF GUN.

Scale of $\frac{1}{4}$.



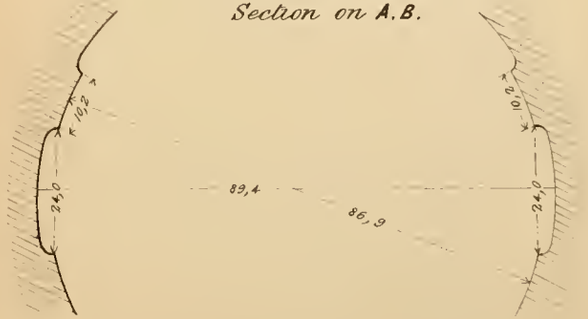
CHAMBER OF PROGRESSIVE TWIST OF GUN.

Scale of $\frac{1}{4}$.



RIFLING OF PROGRESSIVE TWIST.

Section on A.B.



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P

gun; the calibre of the latter, however, is much less. But the horse artillery is armed with a lighter gun than that of any other artillery.*

The weight of the new heavy gun introduced into the artillery is intermediate between that of the light 4-pr. and that of the 9-pr. With this weight, despite the fact that the initial velocity of the projectile of the heavy 4-pr. exceeds that of any foreign gun, the strain on the carriage is sufficiently moderate; while in some artilleries—the Prussian, for example—the gun being light in proportion to the projectile, the strain on the carriage is very severe, as has appeared from experiment.

To judge of the burst of the projectiles, in the absence of the direct result of experiment, let us compare the weights of the projectiles, the number of fragments of the exploded shell, and the bursting charges. This comparison leads to the conclusion that the Russian 4-pr. is not inferior to the guns of small calibre of foreign artilleries.† The 9-pr. gun carries a common shell with a large bursting charge, and the fragments of it are heavy. Its explosive effect is greater than that of any foreign field gun.

With regard to accuracy of fire, comparing the data of the third table, we find it proved that with the proposed armament the Russian field artillery will have a gun not inferior‡ in accuracy to the field guns of the best construction of foreign nations. Its gun will have great tension of trajectory—equal to that which other nations have attained at the sacrifice of severe strain on the carriage.

Finally, the breech-loading system we have adopted gives ample guarantee that the guns will maintain their ballistic power for a long time; while other artilleries which have adhered to the muzzle-loaders, though they may attain great precision of fire by a very careful manufacture in their guns and projectiles, they can only do so for a limited number of rounds.§

PETERSBURGH,
June 1875.

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* It should be remembered that the Italians have no horse artillery.—*Eng. Tr.*

† It would have been better had the author given the manner and data upon which he has gone in making this comparison, inasmuch as the conclusion to which he arrives is one which certainly cannot be admitted without demonstration.—*Ed.* "*Giornale, &c.*"

‡ In the above table giving the results of practice, in default of the direct results of experiment, the accuracy of the new gun is taken as equal to that of the Austrian 8·7c gun. The conclusion come to in the text by mere induction requires the confirmation of experiment.—*Ed.* "*Giornale, &c.*"

§ These tables are of great interest, as an unbiassed judgment of the merits of the guns can be come to by the reader from a different point of view from the writer. But they require one important addition—viz., the number of hits per round of shrapnel on a target of stated dimensions. This seems in most such comparisons a common defect. It is a vital one, too, inasmuch as the chief use of field artillery is for firing at troops, not at walls, houses, guns, or the like—that being only their secondary use. As the science of artillery advances, the larger becomes the proportion of shrapnel shells as compared to other projectiles in the gun equipment, since that shell is exclusively used for manslaughter; and yet the result of firing with this projectile is not taken as the real and practical ground of comparison, as it logically should be. Similarly, we never see the initial velocity of a shrapnel, always of a common shell, given in tables descriptive of gun practice.

The author's eulogium of the light 4-pr. seems so little warranted, that it may be safely predicted that it will soon be superseded by a harder hitting gun.

His opinion of the endurance of muzzle-loading steel field guns must have been formed upon some scarcely defined wish, which gradually engendered an impression, that what he was stating had crystallised into a fact. That opinion can hardly be based upon anything more substantial.—*Eng. Tr.*

THE

7c ITALIAN FIELD GUN (BRONZE).

BY

COLONEL H. H. MAXWELL, R.A.

Dimensions, Weights, &c.

Length of gun (nominal)	5′ 9·5″
" rifling	4′ 2·1″
Preponderance ....lbs.	79·4
Calibre ....ins.	2·953
Twist of rifling, driving edge, 1 turn in cals.	$46\frac{2}{3}$
Do. loading edge, do.	48·3
Weight of gun ....cwts.	5·8
Weight of common shell (7·7 lbs., burster $7\frac{3}{4}$ ozs.)....lbs.	8·2
Length of com. shell in diameters..No.	2·4
Ratio of weight of shell to gun	$\frac{1}{80}$
Weight of gun-charge of powder..lbs.	1·21
Ratio of weight of gun-charge to common shell	$\frac{1}{6\cdot75}$
Weight of shrapnel ....lbs.	9·37
Bullets in shrapnel ($27\frac{1}{2}$ to lb.)...No.	100
Ratio of weight of powder to shrapnel	$\frac{1}{7\cdot75}$
Weight of case shot (61 zinc bullets) lbs.	9
Initial velocity with com. shell ...f.s.	1312
Height of axis of gun above plane...ft.	3·44
Distance between bearing points of wheel and trail on the ground, measured axially ....ft.	4·8

Maximum elevation	22°
Minimum "	3°
Track of wheels	4′ 5″
Diam. of "	4′ 1·6″
Weight of wheels ....each, cwts.	1 0 9
" gun-carriage (empty) "	7 1 8
" limber " "	6 1 5·5
" body of wagon " "	7 1 25·7
Total length of { Gun-carriage ...ft.	22
Total length of { Wagon.... "	21·3
Turning angle of carriage	50°
Length with 4-horse team { Gun ...ft.	33·9
Length with 4-horse team { Wagon "	33
Rounds carried in gun-limber ...No.	46*
Do. in wagon-limber and body... "	112
Weight of gun-carriage packed, inclusive of gun and small stores..cwts.	13 2 9
Weight of carriages packed for service, men not mounted { Gun..... "	24 2 12
Weight of carriages packed for service, men not mounted { Wagon†. "	25 2 21
Gunners who can be mounted on { Gun-carriage. No.	4
Gunners who can be mounted on { Wagon ..... "	4
Draught for each horse in team of 4 { Gun ...lbs.	688
Draught for each horse in team of 4 { Wagon.. "	719

Gun.

System.—Krupp's, with cylindro-prismatic steel wedge and Broadwell's expanding steel ring, or gas-check.

Gun-Carriage.

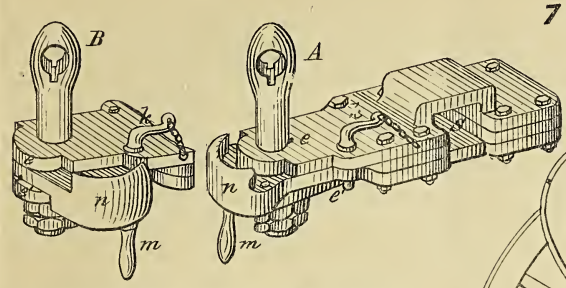
(Fig. 1.)

The carriage is chiefly composed of plate-iron, and consists of two cheeks, *C*, parallel for the length occupied by the gun and thence converging to the point of the trail, ending in the trail plate. The lower surface of the trail-plate eye and the bend of the lower jaw of the plate, which curves under the end of the trail, are at right angles to each other at the point *c*. Three plate-iron transoms, *a*, *a′*, *a″*, and the upper and lower jaws of the trail plate keep the cheeks together. The axle, *e*, of wrought-iron, has no wooden bed, and is let into the cheeks.

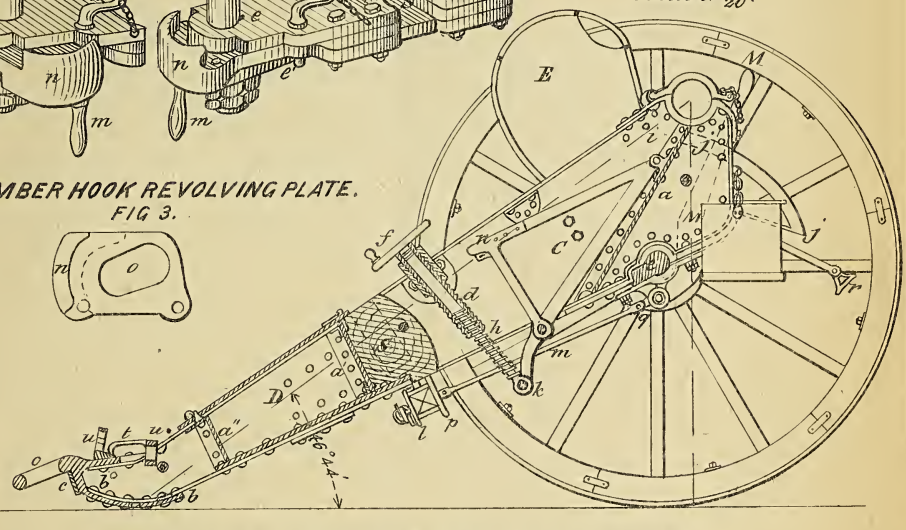
* 46 are actually carried, but there are empty cells for two more rounds.

† Without spare wheel.

LIMBER HOOK.
FIG. 2.

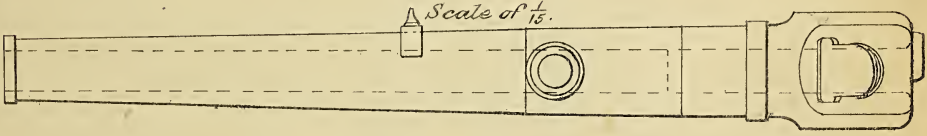


7c B.L. GUN CARRIAGE.
LONGITUDINAL SECTION.
FIG. 1.
Scale of $\frac{1}{20}$.

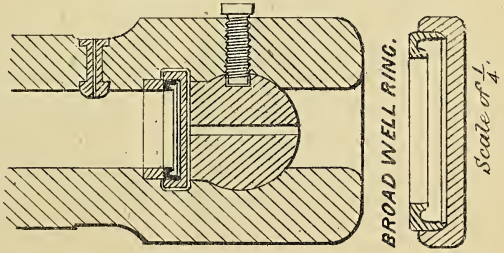


LIMBER HOOK REVOLVING PLATE.
FIG 3.

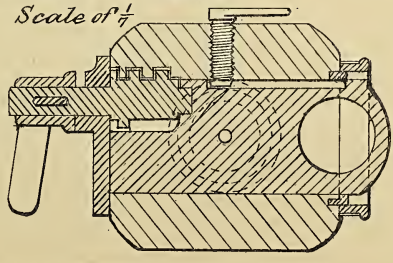
7c B.L. BRONZE GUN OF 5·8 CWTS.
FIG. 4.
Scale of $\frac{1}{15}$.



LONGITUDINAL SECTION OF BREECH.
FIG. 5.



CROSS SECTION OF BREECH.
Scale of $\frac{1}{7}$



The elevating arrangement consists, 1st, of an elevating screw, *d*, moveable in its rotatory nut by means of a handwheel; 2nd, of a second screw, *h*, working in a female screw in the elevating screw, *d*; and 3rd, of an elevating plate and frame *kin*, hinged at *k* and *i*. The breech of the gun rests on the part *n*.

The wheel-locking gear or break—which is generally used in travelling, but is available for checking recoil—is composed, 1st, of a block of wood, *l*, of a length equal to the track of the wheels, suspended to the cheeks of the carriage, and garnished with friction plates, *p*, to bear against the tires of the wheels; 2nd, of a lever, *MM*, connected with the block, *l*, by a rod, *m*, and an excentric, *q*. If the lever be worked upwards the excentric, *q*, acting on the rod, *m*, brings the friction plates, *p*, in contact with the wheel tires. The lever is then fastened by clutching into one of the teeth of a circular rack, *jj*.

The limber hook (Fig. 2) is composed, 1st, of two fixed plates, *e e'*, which encompass the axle at *S*; 2nd, of an intermediate plate, *n*, which is capable of a partial revolution round the pintail. If the revolving plate be placed in the position shown at *A*, its shoulder, *n*, comes immediately under the metal of the limber eye, while its rounded end bears against the right-angled bearing surface at *c* (Fig. 1) below the eye. Under such circumstances, the limber and the carriage to which it is attached are rigidly connected. If, on the other hand, the intermediate plate be revolved into the position *B*, there is no longer contact at *c* (Fig. 1), and the limber and the carriage attached to it are merely linked together—a connection suitable to rough ground, but the weight of the pole necessarily bears down on the wheelers. The revolving plate, *n*, is fixed in either of its two positions by the drop-bolt, *k*; it is further furnished with a handle, *m*, wherewith to revolve it. A drawing of the revolving plate separately is given at Fig. 3. The pintail passes through the hole, *o*. The plate may be revolved into either of its positions with the gun limbered-up, while the carriage is in motion on even ground. To render the connection rigid on rough ground the carriage must halt, and, generally speaking, the pole must be raised a little. This plan is doubtless an excellent one, but is more particularly advantageous in pole draft. In designing the gun-carriage a good many of the innovations proposed by Colonels Mattei and Rossi for the system of artillery described in "Proceedings, R.A. Institution," Vol. VI. p. 325, have been adopted. The track (53 ins.) and diameter of wheels (49·5 ins.) were those of the Mattei-Rossi system of carriages; and it would seem that these were the starting points from which such surprising lightness combined with adequate strength and large store of ammunition were obtained.

Package of Ammunition.

Limber, Gun or Wagon.

There are 48 cells for projectiles in the single limber-box, only 46 of which are occupied; that is to say, 32 common and 12 shrapnel shells (the latter having time fuzes permanently fixed), and 2 case shot;

48 cartridges are packed above the projectiles in 4 cartouches; there are further 45 percussion fuzes in 3 boxes besides small stores. Total, 46 rounds.

Wagon Body.

48 common and 18 shrapnel shells (fuzed); 66 cartridges in 6 cartouches; 48 percussion fuzes and small stores. Total, 66 rounds.

Thus per gun there are with the battery—

	Common shell.	Shrapnel shell.	Case.
2 Limbers	64	24	4
1 Wagon body ...	48	18	0
Total per gun	112	42	4

or 158 rounds per gun.

The Shrapnel Shell.

The vertical section (Fig. 4) will show that this projectile is very much like the Boxer shrapnel, only that the ogival head is formed by a time fuze on the Bormann principle, and that the burster is situated—as in the first Boxer "improved shrapnel"—in the axis of the shell, in lieu of being in a powder-chamber at the base. The bullets are 100 in number, 0·57 in. in diameter, 27½ of which weigh 1 lb.

The accounts of the experiments* mention one fact which, if accurate, is well worthy of notice—viz., "the bullets, before being introduced into the shell, are immersed in boiling oil; they are kept in position by resin poured upon them. This lubrication of the bullets favours their regular dispersion, preventing the resin from binding them together in groups at the moment of explosion." The experiments coincide with those made in England in one point—viz., that the mouth of the shell proper should be as large as possible.

The effect of the shrapnel at known distances is as follows:—

Firing at 50 men in line, at 875 yds., 12 men hit per round, and at 1750 yds. 9 men hit. The slight difference is said to be due to the fact that aim was not taken in the first case at different parts of the target, as was done in the second case.

Firing at 25 men kneeling in line, 3 men for every 2 paces, at the above distances, the result was one-half the effect of the above at each range.

Firing at half a squadron in line of 31 men at 875 yds., 8 men hit per round, and at 1750 yds. 7 men.

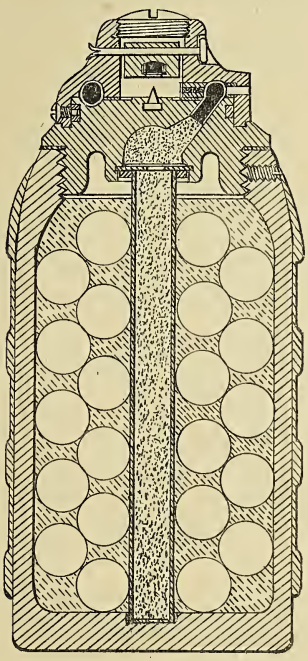
Firing at 25 men lying down, represented by vertical targets 1·64 ft. high × 1·84 ft. wide, and by sloping targets attached to the former

* By Captain P. Barabino, Royal Italian Artillery.

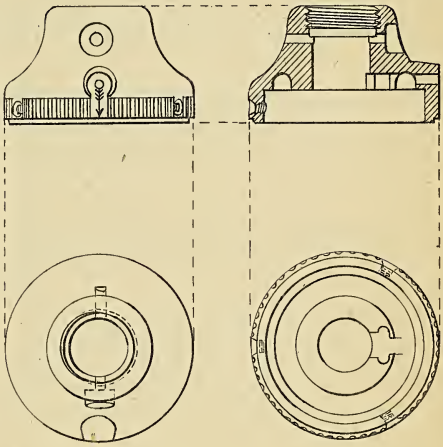
7c SHRAPNEL SHELL.

FIG. 4.

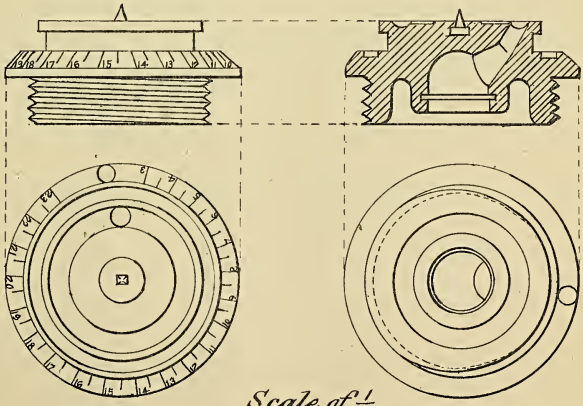
LOADED WITH TIME FUZE.



HEAD OF TIME FUZE.



BODY OF TIME FUZE.



Scale of $\frac{1}{2}$

5·58 ft. long and of the same width as above, the targets being spaced out at 1·64 ft. apart, and the ranges being 547 yds. and 1531 yds., the effects were 2·9 and 2·1 hits per round.

Firing at 2 field pieces unlimbered, limbers with teams hidden in a hollow behind the guns, 1 officer and 1 trumpeter visible between the pieces, the range being 1094 yds., 3 men and 2 horses hit per round, and at 1969 yds. 3 men and 3 horses hit every 2 rounds.

The conclusions come to as to the efficacy of the fire were as follows:—

1. That the shrapnel fire of the 7c gun may be expected to give most efficacious results against men and horses, provided that the battery has had the necessary practice to execute it with that discernment which is indispensably necessary.

2. That against troops in the open, the maximum effect is obtainable by bursting the shell from 6 to 10 ft. above the plane, and at a distance of from 30 to 50 yds. short of the target.

3. That against troops under cover, it is desirable to burst the shell above the ridge of the covering mass, and at such a height as to prevent the lowest shots striking the mass before explosion: the elevation of the piece being that due to a range of 50 yds. greater than the distance of the object fired at.

4. That the system of getting the data for firing with shrapnel by means of a few rounds of common shell, meets the object in a tolerably satisfactory manner; but that that system will be efficacious in the direct ratio of the skill of the officers in the practical execution of this special system of firing.

Common Shell.

This projectile differs from that in the British service only in so far that the inside is scored with weakening grooves. It bursts on the average into 24 pieces, nearly regular in form, weighing at the lowest limit 3½ ozs. each.

Range Table, Common Shell.

Distance of object. yds.	Elevation. degs.	Hits per cent. in a target 5·9 × 196 ft.
547	0·8	100
1094	2·0	83
1540	3·6	45
2187	5·4	23
2734	7·6	—
3281	10·0	—
3828	12·6	—

The elevations for the shrapnel shell are one-fifth greater, the table extending to 2515 yds.

Organisation.

Formation of a Battery of 8 pieces on the war footing.

Guns	8
Carriages	20
Officers	5
Men	164
Riding Horses	17 (1 spare)
Draught "	92 (10 ")

Comparison with other Guns.

	Italian L. Field Battery 7·5c B.L.	English H.A. 9-pr. M.L.	German H.A. 7·85c B.L.
Weight of gun ....cwts.	5·8	6	7·68
Calibre ....ins.	2·953	3	3·09
Preponderance ....lbs.	79·4	10	99
Number of grooves	12	3	24
Length of rifling ....ins.	51	62·3	60·2
Twist in calibres	1 in 46⅔	1 in 30	1 in 50
Weight of gun-carriage, packed ....lbs.	1539	2057	1966
Charge .... "	1·21	1·75	2·75
Initial velocity ....f.s.	1312	1391	1522
Common shell (full) ....lbs.	8·2	9·1	11·2
Bursting charge ....ozs.	7·75	7·5	6·5
Shrapnel (full) ....lbs.	9·37	9·8	12·2
Number of bullets in shrapnel	100*	63	122
Rounds carried (gun and limber)	46	40	40
Total rounds (gun and wagon)	158	148	154†
Weight behind gun-team ....lbs.	2744	3778	3936

Note.—The above table gives the same data for comparison as that published in "Proceedings, R.A. Institution," Vol. IX. p. 296.

General Remarks.

An inspection of a 7c battery of the Italian field artillery at first conveys the impression that it must form a portion of the army of the Kingdom of Lillyput. Everything about it is small; everything remarkable for lightness. The gun, the gun-carriage, the wheels, the teams, the individual horses, and even the men, are small; but everything being in proportion, the eye soon adapts itself to the scale of the picture. When, however, it is found that this battery carries 46 rounds of projectiles averaging 8¾ lbs. in weight with the gun and 112 more behind it in the wagon; that these projectiles are fired at a velocity of 1312 ft. per second with great accuracy; and that the weight behind the team of 4 horses in the gun is only 24½ cwts. and in the wagon 1 cwt. more, the matter becomes one worthy of close examination, in order to find out how this great efficiency is obtained.

* 27½ to the lb.

† 8 ammunition wagons to each battery.

It might appear at the first glance paradoxical to state that the lightness of the equipment is in a very great measure due to the small diameter of the wheels. This statement we will endeavour to substantiate by the following considerations.

The diameter of the wheel, if taken as a starting point, determines very closely the width of track. It further determines the length of the trail—seeing that all artilleries have nearly the same trail angle. It further implies the scantling of the wood and metal work of the wheel within certain limits, and thus the weight of the wheel. It determines indirectly the length of the axles of all carriages, the width of framework of limbers, wagons, &c.

In former days, the height of the gun above the plane was very properly considered an important element in a gun-carriage; for it was argued that with the smooth-bores the greater the range at point blank with a spherical shot which ricochets, the more efficient the gun, and the readier it is to fire case-shot to resist a charge of cavalry. But is that element of the same importance with rifled guns as it was with the smooth-bores of old? The answer may fairly be given in the negative, provided the height of the muzzle be convenient in serving the gun. Case shot being now almost abolished, resort must always be had to the tangent sight at all ranges. If, now, it be conceded to be a fact—which to all intents and purposes it most assuredly is—that the trajectory of a rifled gun at 2000 yds. is precisely the same for a little more than its first half as that at 1000 yds.,* the height of the gun above the plane, excepting for convenience of service, is a matter of no importance. If this be granted, why should not the diameter of a gun-wheel be 4 or 4½ ft. in lieu of 5 ft.? The answer to this question will probably be that the higher the wheel the easier the draught, within reasonable limits. This is true, provided the weight drawn be taken to be constant; but if the weight vary in some direct ratio with the height of the wheel, that answer will not be true. If the weight, for instance, could be reduced one-third by cutting 1 ft. off the diameter of the wheels, it would hardly be contended that the draught with the bigger wheel was the lighter.

Again, if we consider the strength of a wheel, we see that within certain unknown limits the strength—supposing the scantling the same—varies inversely with the diameter; in other words, the smaller the diameter of the wheel, within practical limits, the stronger it is. Or, to put it another way, we may produce wheels of the same strength by using smaller scantlings of materials in a small wheel, than we can in a large wheel. In other words, we can get a proportionately lighter wheel of 4 ft. in diameter equally strong with the service wheel of 5 ft.; and this would have, as above shown, no injurious effect upon the shooting of the gun.

Now, supposing we reduce the diameter of the wheel from 5 ft. to 4 ft., by way of argument, we may reduce the track of the carriages from

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* Consider the trajectory at 2000 yds. on paper to be represented by a bent wire. Pin the wire down at the muzzle point, then cause the bent wire to revolve round the muzzle point until it cuts the horizontal line, representing the range, at 1000 yds.; that portion of the bent wire which is above the horizontal line will represent the trajectory at 1000 yds.

5 ft. 2 ins. to say 4 ft. 2 ins. It need not be explained here how greatly this alteration would at once reduce the weight, not only of the wheels but of the body of the carriages themselves. It may be remarked that with the Italian guns no inconvenience is found in serving a gun of 4 ft. 5 ins. between the wheels. It may be said too that it would be absurd to put teams of the colossal horses of England to draw carriages with wheels only 4 ft. in diameter; that the angle of the shaft would be practically bad—for a great deal of the force of the wheelers would be expended in lifting the wheels of the limber off the ground, as may be shown by decomposing the tractive force vertically and horizontally. That objection would be perfectly fair, but it is an objection the flank of which may be turned. It is not quite impossible, with a little ingenuity and good will, to increase the curve of the end of the outside shaft, near its point of attachment to the axle. As to the inside shaft, it might be attached over the frame of the limber, while the splinter-bar might be raised to the same height as at present, to prevent kicks over.

In the Italian artillery, the height of the axis of the trunnions is 41¼ ins. above the plane—being very closely the height in the British field artillery. The radius of their wheel is 24·8 ins., leaving a vertical distance between the axis of the trunnions and the centre of the axis of the two wheels of close upon 16½ ins. The writer of this paper, with all due deference to the designer, considers this to be a great defect;* it quite unnecessarily raises the centre of gravity of the gun and carriage taken together, and gives rise to upsetting. It is no great palliation of the defect to say that the gun and carriage are so light that if they do upset they are easily righted. Further, it is objectionable in another way. If a line be drawn from the axis of the trunnions to the point of support of the trail on the ground, it will be found that its inclination to the horizontal plane is close upon 45°—nearly double that in the British service. This angle is intimately connected with the "jump" in firing, and it may be presumed that this "jump" with the 7c gun is unusually great—a matter of no great importance, perhaps, provided that it is regular in amount, and that the carriage does not capsize over backwards when the recoil of the end of the trail is checked purposely or by accident. Such a construction would certainly not suit a gun destined for the very high velocities lately introduced abroad.

To continue, then, the subject of the effect of the reduction of the diameter of the wheel to 4 ft. If we were to retain the same trail-angle as at present of 22° or 23°, the length of the trail might be reduced in the direct ratio of the diameters of the existing wheel of 5 ft. and the reduced wheel of 4 ft.; that is, the length of trail might be reduced by one-fifth. A notable gain in lightness and length of ground covered by the carriage would be the result.

Thus, the more the subject is examined the clearer will it be proved

* The defect is recognised by Italian artillery officers; but the existing height of the axis of the gun is thought to be necessary in a country like Italy, where the plains are covered with such tall crops as maize, &c.

that nearly all the dimensions of a gun-carriage are dependent upon the diameter of its wheels; and that if a light gun-carriage and *matériel* generally be *desiderata,* the only feasible way to reduce the existing extravagant weights drawn by the teams of the British artillery is to reduce the diameter of the wheels; and it has, it is hoped, been shown above that theoretically this object can be attained without sacrifice to the shooting powers of the gun or to the strength of the material.

On the introduction of a new piece of artillery into the service, there is always found some one to give an account of its merits. So it was with the Italian artillery. The officer who undertook the task published a pamphlet from which a good many of the details of this paper have been gathered. He seems to write the words of wisdom when he says:—"In making the project for a new system of artillery, in general it is impossible completely to satisfy certain conditions without partially sacrificing others. The criterion of artillery, therefore, consists in giving the preference to the conditions of great importance, without losing sight of those which have only a secondary value; that is, the latter should not be so completely neglected as to give rise to inconvenience in service."*

The more this system of field artillery is examined, the more one becomes convinced that a fair balance of advantages has been struck. Every item—especially in the carriage—has been reasoned upon, worked out by experiment, or got at by analogy or by the adoption of improvements, often judiciously modified, taken from other artilleries. There is nothing arbitrary, or servilely imitated from old patterns, home or foreign: its designers appear to be of opinion that what is good is good, irrespective of its source. Finally, there is a great deal of originality well worthy of the serious consideration of other artilleries.

Comparing the Italian 7c gun with the 9-pr. gun of 6 cwts. of the English horse artillery, the above table of comparison shows that for every 100 lbs. drawn by the Italian, the English team has to draw 138 lbs.

POSTSCRIPT.

Since the above was written, the following more detailed information as to the gun-carriage has been obtained:—

The bracket sides of the carriage are of plate-iron (0·2 ins. thick), with the edges turned down inwards on a suitably shaped anvil. The object of this form is to give stiffness to the trail. The difficulty of turning down the iron occurs when two lines of an irregularly formed profile meet; but it is precisely about the junction of such lines where special fittings are required—as, for instance, at the trunnion seats, the end of the trail, &c. At these points there is no turn over; the plate is riveted between two forgings, after the fashion of a sandwich. This

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* "Le nuove batterie di cannoni da cent. 7 a retrocarica," per C. Pozzi, Cap. d'Art^a. Roma, 1874.

method of turning down the iron to a right angle is a great advance on the angle-iron and riveting all round in the English carriage.

The bracket sides are parallel to each other for about one-half of their total length; they are there bent inwards, and meet between the jaws of the trail plate. The form of the trunnion seat is peculiar. The trunnion, it should be stated, is not cylindrical but slightly tapered from shoulder to face; the trunnion seat is of similar form, but "freed" below the trunnion, so that the lower surface of the trunnion is *not* in contact with the lower surface of the trunnion seat. The trunnion, in a cross section, bears at two points as near the horizontal diameter of the trunnion as possible, so that at the moment of recoil the bearing points shall be in, or as near as possible in the line representing the force of recoil. This ensures the gun and the carriage recoiling together. This, perhaps, will be better understood by considering the reverse case. If the trunnion be supposed to lie very loosely in the trunnion seat, at the moment of firing the trunnion is driven back violently against the trunnion seat; the whole carriage then takes up the motion, after suffering the strain thus suddenly applied. If, on the other hand, the trunnion bear on only two points, in a cross section, and those two points are in the line of recoil, there is no intermediate stage between the recoil of the gun and that of the carriage.

The bearing of the axle-arm in the pipe-box is arranged on the same principle. The clearance or difference of their diameters is very small (0·01 in.)*

The wheel and its axle were imitated from some specimens sent from Woolwich to the Exhibition of 1864 in Paris; consequently they must have been, judging from the date, the original Madras-pattern wheels. The Italian form of that wheel and axle seems to have succeeded admirably, while the English attempts in the same direction can hardly be said to have done so.

The length of the pipe-box in the clear is 7·4 ins. The inside diameter of the aperture is 2·254 ins. and the outside 1·713 in., with a length between these diameters of 7·2 ins. It is of hard bronze, and has oil channels cut internally which end in two circles at right angles to its axis at a short distance from the faces.

The nave is of cast-iron in two pieces, one being a movable disk with a central hole which fits the taper of the fixed piece and leaves a distance between it and the circular flange of the fixed piece equal to the width of the shank of the spoke. The width of the nave is 7·2 ins.

The gun-carriage axle is of iron. The body is cylindrical in the centre and tapers slightly towards the shoulder. There are no holes in it. The length of the arm in the clear is 8·27 ins., a length of 0·4 in. next the shoulder being parallel to the axis; the remainder is taper. The diameter at this shoulder is 2·24 ins.; while that of the body at this part, bulged out slightly to a trumpet shape, is 2·6 ins. On this is shrunk

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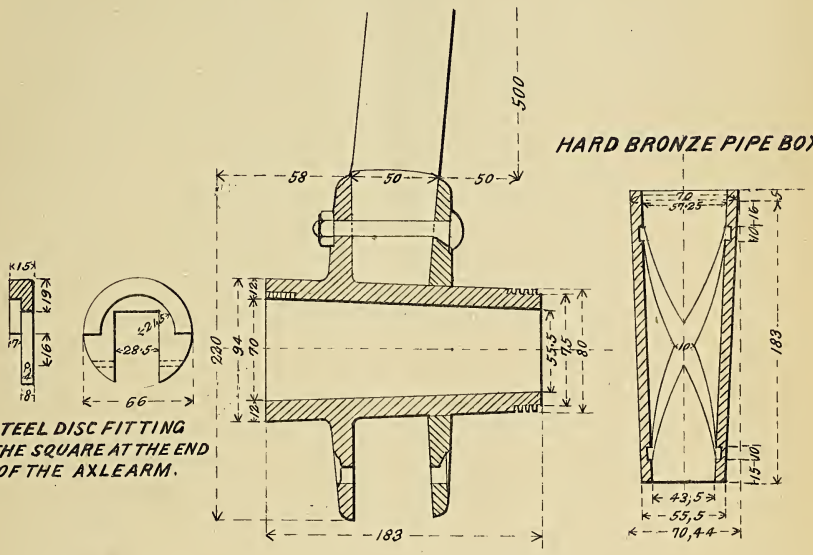
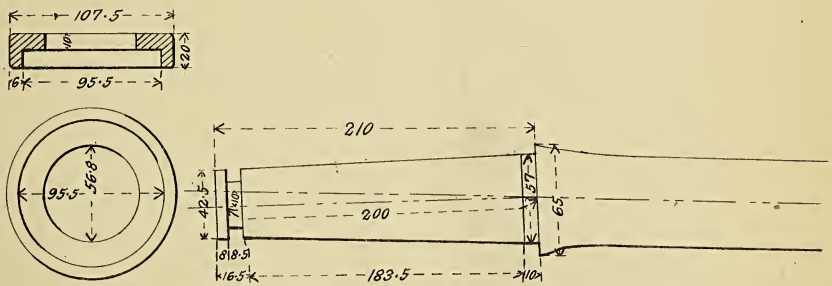
* It is stated by the best possible authority that the clearance between the axle-arm and the pipe-box is all towards the front of the gun-carriage, and that contact is thus ensured between the two surfaces towards the rear, and that at the moment of recoil there is no jerk in finding the bearing. How this is effected is not very clear.

CAST IRON NAVE.

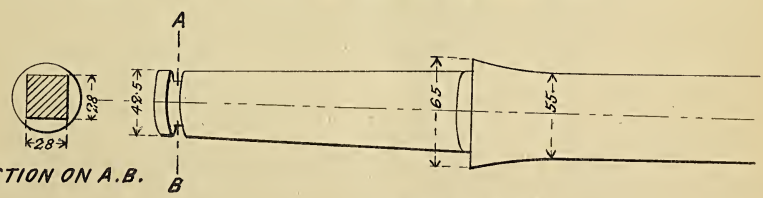


STEEL DISC FITTING THE SQUARE AT THE END OF THE AXLEARM.



STEEL SHOULDER SHRUNK ON TO AXLE.

WROUGHT IRON AXLE.



SECTION ON A.B.

SCALE OF $\frac{1}{5}$.

DIMENSIONS IN MILLIMETRES.

hot a steel ring 0·79 in. in width; one-half of the width being bored out so as to fit the shoulder when expanded by heat (shrinkage 0·008 in.), the other half bored out to 3·76 ins. diameter. The inside of the cast-iron nave (3·7 ins. in diameter) works in and bears against this steel ring. The bearing surface of the axle-arm is 7·22 ins. in length, measuring from the outside edge of the shoulder horizontally. Beyond this point, the metal is cut away so as to leave the cross section of the arm a square inscribed in the original circle. The width of the recess is 0·335 in., and the side of the square is 1·1 in. Into this fits a movable steel disk with a square cut out of it, so as to form a fork and to drop into the recess prepared for it in the axle-arm. The upper part of the disk, however, has an outward semi-circular shoulder about double the width of the thickness of the disk. It is kept in its place by a pin running through the ends of the fork just under the square on the axle. The outside of the nave and pipe-box runs against this disk; thus the wheel runs between two steel disks endwise and internally on the taper arm with a clearance of only 0·01 in. As, further, there is ample provision for oiling (such is the lubrication intended, as oil is more easily procured in Italy than grease), and as dirt is prevented from entering 'twixt nave and axle by a cap screwed over the end of the cast-iron nave, the wheel runs truly and easily. The pipe-box can suffer but little wear, inasmuch as the steel shoulders prevent the wheel from canting from wear, as it would were it not for the end support.

The dip or hollow of the axle-arm is $\frac{1}{20}$, whereas the dish of the wheel is $\frac{1}{10}$; consequently the lowest spoke is not perpendicular to the ground. This construction is justified by the following considerations:—Looking at the carriage from behind, and supposing the road to slope from right to left, the strain on the lowest spoke of the near or left wheel is much greater than on that on the corresponding spoke of the off or right wheel. It is desirable, then, to have that spoke as nearly vertical as possible, to resist the extra strain on it.

If this reasoning be sound, the lowest spoke should not be vertical on level ground. Now, if reference be made to our text-books, it will be found laid down that the "downward inclination or hollow is given to the arm for the purpose of bringing the lower or working spoke vertical, the wheels being on the *level*." But both the wheel and axle without this arrangement are amply strong on a *bad* road when the weight acts symmetrically on both wheels of the carriage. It seems unnecessary in such case to make special arrangements for the better support of the weight; but, on the contrary, that such should be made when that weight bears upon one wheel more than on the other, as in the case of a sloping road.

The axle-arm is in prolongation of the axis of the axle. In other words, it has no "lead."

The length of the axletree, or extreme width of the carraige (61·47 ins.), was adapted from the width of a pair of horses in draught. It was observed that when horses pull they incline towards each other, and when they back they incline outwards. The distance between the outer flanks of the horses was measured under both circumstances, and

the mean of the dimensions taken as the extreme length of the axle. It is very closely 1 ft. less than that in the English service. If the principle of having as short a pipe-box as possible, consistent with the construction of a strong wheel with metal nave, be adopted in connection with the above detailed hollow of axle-arm and dish of wheel, the width of track naturally follows.

In the 7c gun-carriage, an equilateral triangle constructed on a base of the distance between the outsides of the tires as they rest on the ground, gives the height of the centre of gravity of the gun and carriage combined. Thus the upsetting angle is over 60°.

ROME,
February, 1876.

THE NEXT STEP IN FIELD ARTILLERY PROGRESS.

BY

LIEUT.-COLONEL FOX STRANGWAYS, R.A.

Amongst all the subjects which may be treated in these papers, there is none of higher interest to us as a corps, or more deserving close attention, than that of the part field artillery ought to take in war, and the means by which its effect should be prepared in peace.

Much will be justly expected of us; how are we qualifying ourselves for the trust the country reposes in us, and how far are we prepared to maintain and advance the reputation our predecessors acquired for us?

Let me say, first, I do not intend to discuss questions of *matériel.* I believe our weapons will at least compare with those of our neighbours. Full knowledge and experience are brought to bear on this subject, and we are not likely to fall behind in mechanical and manufacturing supremacy at present, and in any case it will be time enough to complain of our tools when we are quite sure we know how to use them. The question of the *personnel* is the important one, and I propose to examine—

1st. What a well instructed and efficient field artillery ought to be able to do.

2nd. In what respects we fall short of such an ideal.

3rd. How our weak points can be made good without the sacrifice of any perfection we have yet reached.

The first essential of an efficient field artillery must be to be able to shoot well; all else is but a means to an end. Whether we consider the points which are equally necessary for all arms of the service—discipline (with all that it includes), cleanliness, smartness, appearance under arms, good conduct, cheerful ready obedience under all circumstances, the high *esprit de corps* which regards military honour as the first of all virtues; or whether we look at the points which are peculiarly the province of the artilleryman—such as the special care of his guns and horses, exactness of drill and movement, readiness of resource in the varying conditions under which his arm is employed; all are but the first steps to the object for which the service exists. They must be made with infinite pains, no trouble is too much to spend on them, they are necessary in the highest degree, and they take time. Herein is the reason for a permanent force—the reason that a volunteer force

can never take the place that its public spirit and intelligence seem to demand. But when these military and technical qualities are thoroughly mastered; when they are a part of the artilleryman's nature—as they must become; there remains the crucial question whether he can employ his arm with its fullest effect against an enemy.

To shoot well seems, at first sight, a very simple thing; but if we consider all that it implies, it will be seen that there is work enough before any service that undertakes in earnest to study and accomplish it, and that the world has never yet seen anything approaching to the full effect that modern field artillery may produce. It implies, on the part of the leaders, a perfect knowledge of the power of their guns and of the effect of their different projectiles under all the varying conditions of wind, soil, slope of ground, the formation of the enemy and the cover he can obtain; of the effect of greater or less command upon their own fire, and the effect of accidents of ground in sheltering their own guns, or making the range more difficult for the enemy to pick up. It implies also such an eye for country that there shall never be hesitation in moving guns by the easiest line from point to point. And this knowledge must be so ingrained as to require no conscious process of thought—to be as much a man's own as his words of command. In no other way can he employ his arm as favourably as circumstances allow. It is evident that his practical course in the field must always be the best one open to him—not the best in the abstract; but he will never take the best course relatively if he has to go back in his mind upon the absolutely best use of his guns and ammunition. His whole mind must be free to receive the instructions of his superiors, to understand their spirit, and to carry them out intelligently, with or without orders, as the circumstances change. Moreover, the actual superior officers of artillery are not the only leaders it is necessary to consider; all officers—indeed, many N.C. officers too—are possible leaders. At any moment on the field of battle the juniors may succeed to command—command for which they will be very helpless if they have no knowledge beyond the requirements of their own immediate work; and in nearly every case the junior officers must eventually become the seniors, and the requisite knowledge should precede and not follow the assumption of command.

For all ranks the power of good shooting means that the art of laying guns, of covering them, of passing them over obstacles, and handling them under the exigencies of the service with readiness and resource; the power of rapidly estimating distance, knowledge of ammunition (especially the bursting points at various ranges of shrapnel)—all these things, which appear simple enough but nevertheless require much practice, should be known, not merely in some out-of-the-way corner of the mind, and amongst a few, but amongst all, as intimately and as much a matter of course as the routine of parade movements or stable duties.

Depend upon it, the instruction of even the humblest gunner in a battery cannot be carried too far, provided nothing of his own proper and immediate duty is sacrificed. Idleness is called justly the root of all evil; but employment without sense or reason is nearly as bad. I

am far from saying that in practice every artilleryman can be made a master of his art. When the utmost has been done, enormous deductions must be made from such an utopian view; but I do say that we ought to set such an ideal before ourselves, and the higher we aim the greater measure of success shall we attain.

The introduction of rifled guns has done something to increase the relative effect of artillery; but, standing alone, the improvements in small-arms have again redressed the balance. The latest example on a large scale is, of course, the war of 1870–1; and although the German artillery—being then entirely armed with rifled guns, and having improved in certain points of tactics brought to light in 1866—undoubtedly made a better figure in the French war, it will not, I think, strike dispassionate observers that the relative superiority of artillery was much greater than in the beginning of the century.

Nor is this to be wondered at. If we turn to our experiments on Dartmoor and elsewhere, it is brought home to us in an extraordinary degree how little is the effect of common shell upon troops in the open; and we cannot fail to see that the effect of rifled guns in war has been obscured altogether by the want of a proper projectile.

If, again, we look at our own records of experimental practice, we shall see equally clearly that shrapnel, or kindred projectiles, are surely filling the void. To go no further than the experiments on Dartmoor last summer, nobody can have witnessed them without a conviction that the use of shrapnel from rifled guns will revolutionise the application of artillery, and must exercise as great an effect upon the tactics of the future as the introduction of breech-loading small-arms.

It is unnecessary to enlarge upon this. It must be plain to every artilleryman, and to every soldier who has given any attention to the subject, that the effect of artillery has hitherto been child's play to what it is capable of becoming, and will surely become in the next war.

For this, however, the soundest and most untiring practical instruction in all that goes to make up the art of shooting is needed. Without it all other excellence is worthless; the artillery that has it not is but a broken reed, the sport of its better taught and more far-seeing opponents. How nearly do we approach such an ideal as I have sketched?

In matters of discipline, drill, movement, appearance under arms, by common consent we stand high; the persistent efforts to improve them have borne fruit, and if there are still imperfections, they are mainly such as must be expected in any human machine. There are of course blots even in the matters we most pride ourselves upon—notably, the neglect of horses by a large number of men when compulsion is removed. It has often been said that the Englishman, with all his love of horses, is the worst horsemaster in Europe; and I am sure general experience will bear me out in saying that only constant, close supervision makes many men take any care of their horses. This may work in peace, whilst the supervision can be given, but it does not improve the idle and ignorant; and when the pressure is taken off—as it must be in the field—there is no good motive to work upon. If we persist in tying gunners and drivers always to N.C. officers, we take

away all sense of responsibility, and destroy the germs of a military spirit: we take a course which no employer of labour, or master, would dream of doing, and we reap our reward in the helplessness and ignorance of many men who under a better system would make excellent soldiers. It is a libel on the men of the regiment to say that it is necessary, though of course innovations would at first lead to some irregularities. Naturally, recruited as our army is, there are some men incapable of being influenced by any good motive; but they can be got rid of, and I am confident the *morale* of the regiment would receive an enormous impulse if all ranks were in their degree more trusted and made responsible for their actions.

On the whole, however, it would be hypercritical to find serious fault with the discipline and drill of the corps, with all that leads to success and renown in peace. There are motives enough to push us to excellence in these points. It is pleasant to hear a chorus of praise of ourselves and of our corps; but it is just when all men speak well of us we are in danger of relaxing our efforts—we think to-morrow shall be as to-day, and are satisfied to ask no more.

Unhappily, success in war and success in peace are by no means the same thing. In peace we demand pomp and circumstance, polish, glitter, fat horses, perfection in parade movements; and we get them because they are things that pay. In addition, we get a certain amount of field movement and gunnery, ever varying in kind and degree, to meet the views of our immediate chiefs. The efforts made in this way are individual efforts to promote a better state of things; but they attain only partial success, because there is no settled regimental public opinion to back them.

I do not undervalue the improvement in knowledge of gunnery that has taken place in late years. I know that much pains has been devoted here and there to the subject, and the general level of instruction has been raised; but our needs of better instruction have increased in a greater proportion, and I assert that our efforts are spasmodic and disorganised, that our knowledge is too much a matter of theory only, to be rubbed up now and then for an inspection or for an annual practice, and not like our drill and ordinary routine, a part of ourselves.

There is no need to dwell upon details, or to seek for instances. Will it not be generally allowed that the sort of question and answer gunnery that too often obtains, the dead level of important and unimportant details, the inefficiency of our annual practice, all betoken but a listless belief in the necessity for good shooting, or at least in the need of any active efforts to acquire it?

How then shall we add to the efficiency we have already reached the further excellence that we need?

It is the listlessness of which I have spoken that is at the root of failure. If opinion in the regiment was convinced that good shooting was essential to success in war, and that it was worth while to work for it, the greater part of the difficulty would be overcome.

We can do much for ourselves. Let us cease the eternal rivalry of spit and polish, and whilst not valuing appearance less, value shooting more. For the moment, at all events, we can rest and be thankful for

the brilliancy we have reached, and can let other needs have their turn. If it is understood that the reputation of a battery depends in some measure on its shooting and its readiness for war from a war stand-point, there will soon be improvement in these respects. We shall then find sound knowledge extending beyond the level of intelligent Nos. 1 and limber gunners, and a real interest in the work taking hold of all. That is always the case when artillery knowledge gets beyond the dry details of standing gun drill and catechism.

It is most necessary that the higher knowledge should be widely spread. Every man on a peace establishment is a possible N.C. officer or important gun number. In our present circumstances, the act of mobilisation on a large scale would cause enormous changes in all ranks. Officers, N.C. officers, and men would in many cases be moved on promotion and to fill up gaps; and even had we more reserves to fill up from, there would be the same necessity for the largest possible backbone of trained men. In these days there is no time to supplement deficiencies in training after the campaign opens; the first great battle is probably decisive of the campaign, and such as the peace training has made a battery it must be in the decisive struggle, weighted heavily too by the changes and augmentations on mobilisation, and the certain loss of valuable men, even in the first weeks, by casualties.

It is much better not to lay down a minute system of instructions. The commanding officer of a battery is the proper instructor of his battery. He should be held responsible for results without fuss as to the manner of his getting them. Let him clearly understand that his reputation depends on it, and leave him free.

I said that if we were of one mind on this subject, the greater part of the difficulty would be overcome. Not that we can do all that is wanted, as matters stand, though we can do much; but we should soon get what more we want if the country clearly understood the necessity of what we ask. When the gun drill, laying, ammunition, fixing fuzes, and principles of gunnery have all been so taught in the barrack square to every man of a battery that he knows them without hesitation, or even thinking about them, then comes the application of his knowledge in the field.

This cannot be satisfactorily carried out with our present means. The annual practice may not always be made the most of, but it is at the best very unlike reality, and is too limited, even if the practice grounds were better.

The obvious want is to carry out practice on varied and extended ground, where the conditions may be made to approach those of service, and to imitate them exactly (save in being shot at) where a range can be found extending in all directions. But a year ago this was said to be impossible; but the practice last summer proved Dartmoor to be admirably suited for it. Half-a-dozen more grounds might be found in England and Ireland—Salisbury Plain, the Shropshire moors, Wicklow, and other places; for artillery practice, with ordinary precaution, is no more dangerous than rifle shooting, the sole element of difficulty is in the range of an occasional blind shell.

In these situations summer camps should be formed, and the batteries, in larger or smaller numbers, succeed one another. It would be foolish to lay down beforehand a course which must be in the first instance experimental; but I think that, provided batteries came to the camp thoroughly efficient in all preliminary work, three weeks, and twice the amount of the annual practice ammunition, would be all that was needed; and this kind of practice every second, or even every third year, would be infinitely more beneficial than the present system. At or near stations where it is possible to get an ordinary range, a small quantity of ammunition might be used with advantage in the off years to enforce and illustrate the drill and theory. Probably three batteries in camp at one time would be found enough, and this number would employ the time better, as two batteries could shoot daily—one morning and one afternoon—and one would be available for fatigues, carrying targets, making works, &c.

The course would comprise deliberate practice, with carefully measured results, to teach the men the effect of their guns and projectiles under all circumstances, followed by practice under the conditions of service; every variety of ground, of weather, of the enemy's formation, and his power of sheltering himself, being tested and illustrated as far as circumstances allowed. In addition, the tactics of the arm, the passage of obstacles, and all the exigencies of service in the field, would be studied. The camps should be camps of artillery instruction in the widest sense, but above all things camps in which no buildings, no permanent staff, no nurses of any sort, should be allowed to appear. The regiment wants to be taught to run alone, and it is only so that we shall know what we have got to trust to when the pinch comes.

In order to make good artillerymen, we must make all ranks see that it is to their advantage to become such. If the officers know that their reputation depends on it, they are quite sure to work for it, and the men too will have a strong motive to the same end; but we ought to give every possible help to this spirit. I hope the promise of reward for skill at arms in the artillery will not be left longer in abeyance. It surely ought not to take so many years to devise a practical scheme, and it is rather scandalous to see a sum of money taken year after year in the estimates, and not applied. The Volunteers have already established a system, and I believe in India we have ourselves done something.

Soldiers crave distinction; a little reward, a little praise, will produce any kind of professional excellence that is wanted. Our shooting is done far too much in a corner. No general officer thinks it his business, or cares to inspect a battery at practice, or to know anything of the results, and no praise or blame is given to those results, whether good, bad, or indifferent.

If, then, we fail to carry the practical knowledge of our arm to the point which improved construction and equipment fairly demand of us; if, in common with other European artilleries, we have not grasped the enormous power which the progress of invention has put in our hands; it is time to look our position fairly in the face.

However my friends may differ on the degree by which we fall short

of perfection, I am convinced none will deny that there is great room for improvement.

The power that is to work that improvement must come from ourselves; we cannot expect the country, or even the military authorities, to take the initiative in reforms which are our especial business. If *we* say we are satisfied, who is to gainsay us? We shall go on in a fool's paradise until the day comes when we shall be tested, and perhaps found wanting.

In the earnest hope that I may induce others to consider this subject —those who, from their abilities and just weight in the regiment, may give a real impulse to it—that so a public opinion may be formed, to demand with one voice what is wanted to carry us to perfect efficiency, I submit these remarks to my brother officers.

JANUARY 10, 1876.

NOTE.—Since this paper was written, the Report of the Dartmoor Committee has appeared. I am happy to see that the view I have attempted to put forward is supported by the conclusions of so influential a body of officers, and still more glad to learn that there is a probability of many of their recommendations being carried out.

The object of these remarks is therefore partly attained; but as the success of the best matured schemes for the improvement of gunnery must depend in great measure on conviction amongst those who have to work them, I think that an effort to rouse opinion in the regiment to the importance of the subject may still not be ill-timed.

MARCH 27, 1876.

NEW (WROUGHT-IRON) CARRIAGES.

FOR

FIELD AND SIEGE SERVICE.

BY

MAJOR W. KEMMIS, R.A.

25-pr. M.L.R. Gun-Carriage and Limber, Mark I.

This carriage is similar in construction to the 16-pr. gun-carriage Mark II.;* having the same wheels, but with an additional bearing-piece riveted round each trunnion-hole.

The elevating gear is of the worm-wheel pattern, similar to that of iron siege carriages; the worm wheel being made composite, to allow of some slip on firing, and so reduce the shock upon the parts. The carriage is also fitted (like siege gun-carriages) with a wooden stool-bed, large quoin, hand quoin, and scotch, which can be used for laying the gun in case of the worm-wheel gear being damaged.

The other fittings of the carriage are the same as for the 16-pr.—viz., for axle-boxes, drag shoe, wadhook worm, &c. The axle-boxes are similar to those for the 16-pr. carriage, but without guard-irons and steps, and only fitted to carry small stores.

The limber is the field limber, Mark II.,* the "off" and "near" boxes carrying each 9 rounds: the projectiles steadied by cleats and fitted with lifting straps.

	cwts.	qrs.	lbs.
Weight of carriage, empty	14	3	9
" limber "	11	1	0
" side-arms "	0	0	19

40-pr. M.L.R. Gun-Carriage, Mark II.

This carriage being designed to take the 6·3-in. M.L.R. howitzer, as well as the 40-pr. M.L.R. of 34 or 35 cwt., is made much stronger than Mark I. carriage,† which only takes the 34-cwt. gun, and from

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* Described in "Short Notes," p. 170 (issued with "Proceedings, R.A. Institution," Vol. VIII. No. 6).

† Described in "Short Notes," p. 174 (issued with "Proceedings, R.A. Institution," Vol. VIII. No. 7).

which it differs in having a third transom, one strong stay to the near transom, and stronger stays to the axle-bed.

The elevating arc used when the howitzer is mounted is special to the latter, and requires an additional pinion to carry the motion to it, on account of the shortness of the piece.

The carriage is fitted with a stool-bed, large and small quoins, and scotch, &c., as Mark I.

The limber is the wrought-iron siege limber* (as for Mark I. carriage); the "off" and "near" boxes carrying each 6 projectiles, steadied by cleats and fitted with lifting straps; the "centre" box is the same as for the 16-pr. When the carriage is used for the howitzer the limber carries a special box instead of ammunition boxes, which is fitted for taking stores.

			cwts.	qrs.	lbs.
Weight of carriage, empty,		for 40-pr....	30	3	16
"	"	" for 6·3 how.	31	0	8
"	limber	"	13	0	4
"	side-arms	"	0	1	3

Forge Wagon and Limber.†

This wagon is Mark II. 9 and 16-pr. ammunition wagon, modified and adapted for carrying a forge, artificers' tools, &c., as follows:—

The sides are not connected to the perch by plates, but in rear by a piece of angle and in front by a piece of bar iron. The frame thus formed is boarded over, sides hinged to it, and the body completed by a movable head and tailboard. This is divided into two compartments by a cross sliding partition: in the rear compartment the forge is carried (its legs folded under it), and in the front the artificers' (smiths' and wheelers') tool chests. Both compartments are covered over—the rear by a lid hinged to the partition board, the front by two movable boards (and a flap) which, together with the tool chests, removed from the wagon, will form a wheeler's bench and collar-maker's cutting board (of lime).

To admit of the forge‡ being worked on the tailboard (as well as off the wagon), the latter is covered with plate-iron and has chains to secure it in a horizontal position, while props are attached to the perch and to the body, in rear, to steady the latter.

The wagon has four under boxes, and is covered by a canvass cover on four bale hoops.

The anvil and anvil block are carried upon the perch; the water-

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* Described in "Short Notes," p. 174 (issued with "Proceedings, R.A. Institution," Vol. VIII. No. 7).

† This wagon not being adapted for carrying the large field forge with bellows now in the service (no longer to be carried in the general service wagon), it is intended to convert Mark I. ammunition wagon for that purpose.

‡ The forge for this wagon is not yet finally approved. One with a fan blast is under trial; it has the same hearth as the present field forge (Mark II.), but is otherwise lighter and more compact in construction.

trough with the forge. The wagon has fittings for carrying, in addition to these, a box of farriers' tools (another set being in the smiths' chest), a box with lanterns, a sack of coals, grindstone, pit saw, crow-bar, picket posts, &c.

The smiths' and wheelers' tool chests open at the end, and the tools in them are packed in drawers; so that on removing the head-board of the wagon, the tools can readily be got at.

The limber is Mark II. field limber, fitted with one large box for spare iron work, and for carrying a box of collar-makers' tools on the platform-board. There are also fittings on the footboard for securing the grindstone when the latter is required for use.

	cwts.	qrs.	lbs.
Weight of wagon body, empty	12	3	18
" limber "	10	3	22
" wagon body, packed	30	2	0
" limber "	14	2	24
" forge (about)	3	0	0
" anvil, block, &c.....	0	3	14
" wheelers' chest, packed	2	3	8
" smiths' " "	3	0	0

Store Wagon and Limber.

This wagon is identical with the preceding, except in a few minor details.

The rear compartment is fitted to take a "stationery" box, which fills the rear portion of it, leaving a small space between itself and the partition board, which is accessible from the top. The front of the box can be let down on the tailboard when the latter is supported by its chains, to serve as a writing desk. The interior of the box is divided into convenient compartments and pigeon-holes. Two stools, and a stand for the box when removed from the wagon, are carried.

The front compartment is fitted for spare stores and horse-shoe boxes.

	cwts.	qrs.	lbs.
Weight of wagon, packed	28	0	0
" limber "	13	3	14
" stationery box, empty.....	1	0	7

February 28, 1876.

SHORT NOTES ON ERECTING PORTABLE SHEERS IN CORK HARBOR FOR LIFTING 35-TON GUNS, 1875-6.

BY

LT.-COL. DENIS-DE-VITRE, R.A.

Site of the Sheers.

The ordnance side of the Island of Hautbowline, more particularly that part affording wharfage, is extremely limited, and does not admit of the sheers standing perpendicular to the shore; they are therefore erected parallel thereto, so as to plumb the small dock into which War Department vessels delivering the guns are warped, stern foremost.

Description of Sheers and Gearing.

Guys, Holdfasts, &c.

The sheer legs consist of two Oregan spars, 70 ft. long, 30 ins. in diameter at the butt and middle, fitted with head gear of cast-iron caps each, and a wrought-iron centre-piece.

The shoes of oak, iron-bound, 6 ft. diameter, 2 ft. deep, connected together with a $1\frac{1}{2}$-in. tie-bar, at 25 ft. apart, and 15 ft. withdrawn from the edge of the dock.

The back guys (two) each consisting of five lengths of 2-in. selvagee wire rope, shackled together, each guy hooked to a $6\frac{1}{2}$-in. rope running tackle of two 18-in. treble bothways blocks, and secured each to chain holdfasts of $1\frac{1}{4}$-in. short link, of 8 fathoms each, applied double, with a 9-in. ring in the centre and an 8-in. × 4-in. link at each end.

Fore guy.—For this purpose an 8-in. 113-fathom coil of rope was supplied; but it was found more convenient, as hereafter appears, to convert the fore guy of the small auxiliary sheers into the fore guy of the large sheers. Four returns of 6-in. rope were thus used.

The holdfasts for the back guys.—Eight posts, picket, 9 ins. × 9 ins. × 13 ft., seven deal planks 3 ins. × 12 ins. × 14 ft., and two oak skids 15 ins. square and 14 ft. long, were supplied for each holdfast; but on opening the ground somewhat over 160 ft. from the feet of the sheers, it proved to be solid rock. The two oak skids only were used, being let into the rock—the rock faced with concrete by the Royal Engineers. The chains were applied double, the skids loaded with "pig-iron" and earth, each holdfast being further loaded with several smooth-bore guns and 8-in. shell.

Front guy holdfasts.—Two anchors, chained together and loaded, were used for the front guy holdfasts.

The main tackles consisted each of a tackle of two 18-in. treble bothways blocks, and 6½-in. rope.

The running tackles for back guys are exactly a duplicate of the main tackles.

Winches.—Four crab winches, strong pattern, are used—two to work the main tackles, and two for the runners of back guys.

Slings are of 12-in. rope, intended to be used double, being 21 ft. long. There are two—one to be applied before, and the other behind the trunnions, and lashed together under the blocks of main tackles.

NOTE.—No driving apparatus was supplied to drive the "posts, picket," 9 ins. × 9 ins. × 13 ft. A monkey for this purpose would be necessary in soft ground.

DETAIL OF OPERATIONS OF RAISING THE SHEERS.

1. The spars having heen landed close to the dock, they were placed on rollers and their butts loaded with "pig-iron," till the centre of gravity was brought far enough back to allow of their being launched across the dock till their head rested on rollers on the other side.

2. In this position the head gear of the spars was pinned, and two light uphers securely lashed, one near the butts, and the other about ⅔ yds. up the spars.

3. The Royal Engineers had meanwhile sunk a solid foundation of concrete for the shoes, on which in due course the butts of the spars were placed, resting on a cushion of soft wood and junk, to prevent the sharp edge of the bowl of the oak shoes cutting the foot ropes or injuring the spars.

4. The foot rope consisted of a chain passed through two strong eye-bolts in the face of the dock, the ends brought up opposite the shoes. A heavy gyn tackle was then hooked to the chain, and the other block was lashed round the butt. The running ends of the tackles passed round the shoes, so that the tackle could be eased off by one man, or tightened up by one of the winches, if necessary, extra ropes being used as preventors.

5. The centre line of the whole system was made to coincide with the line adopted on a previous occasion in erecting 45-ft. sheers, and the old holdfasts and old shoes were utilised in re-erecting those sheers. This completed, the 45-ft. sheers stood between the legs of the 70-ft. sheers.

6. The main tackle falls of the 45-ft. sheers were now lashed to the large sheers at the upper upher or cross spar, and a barge lent by the navy was grounded at low water in the dock.

7. The navy lent a quantity of old skidding, which was built up

on the deck of the barge till the sheer legs were reached, and the returning tide raised the head of the sheers.

8. The winches intended for the main tackle falls of the big sheers took in the slack of the main tackle falls of the 45-ft. sheers, and shortly took the weight altogether from the barge.

9. Soon after, the winches of the back guys of the 70-ft. sheers coming into play also, the sheers were erected in three hours after taking the weight, without a hitch.

10. Meanwhile, when the 45-ft. sheers took the weight, its fore guy was unrove and applied as fore guy to the big sheers, to save time and trouble.

11. The small sheers were afterwards lowered by their own main tackle falls, and the big sheers raked to stand over about 15 ft., till required for use.

QUEENSTOWN,
January 1, 1876.

PRÉCIS OF THE FRANCO-GERMAN WAR.

BY

CAPTAIN S. C. PRATT, R.A.

PART I.

SAARBRÜCKEN TO METZ.*

Cause of war.

To review the political causes of the war of 1870, and sketch the tortuous course of policy which placed Prussia in the position of leader of the German race, would entail a study of Continental politics from the commencement of the century. By violation of numerous treaties, by wholesale annexation of the minor states, and finally by the expulsion of Austria from Germany, she became invested with the military supremacy, and a popular war with a foreign power was all that was necessary to re-establish the ancient German Empire and secure the long desired unity of the German peoples. In France, on the other hand, the growing power of her ancient enemy, the astounding successes of the six weeks' war, and the unsuccessful attempts to obtain a rectification of the Rhine frontier, had aroused a feeling of bitter hostility. France alone was determinedly hostile to German unity; Russia was open to an arrangement, Austria was too enfeebled by the Sadowa campaign to interfere, and England had notoriously withdrawn herself from the complications of Continental politics. The pretensions of the two great rivals had to be decided on the battle-field, and the immediate cause of rupture is a matter of little importance. A diplomatic quarrel arising from the offer of the Spanish throne to the Prince of Hohenzollern-Sigmaringen afforded a plausible pretext for war, which was formally declared by the French on the 19th July, 1870.

Previous to entering upon a description of the campaign, it will be necessary to refer briefly to the system of recruitment and comparative military position of the two rival armies.

* This short *précis* of the 1870–1 campaign has been written in the belief that it will be acceptable to many officers who would not consult a more lengthy account. It may also be of advantage to those entering upon the study of the campaign; forming, as it does, a framework the details for the filling up of which are at hand in the many histories now issued. Some difficulty has been experienced in finding out the actual numbers engaged in the several battles. The German official accounts, though perfectly accurate in the detail they give, do not take into consideration the troops outside the zone of fire, who in many cases affected the result of the engagement. For this reason, in more than one instance, the approximate numbers given by Lecomte have been adopted. To compress the description of several distinct campaigns into a few pages necessitates the omission of many minor facts and the suppression of much detail. How far the judgment of the writer has been sound in his work of excision must be left to the opinion of the military student.

The military organisation of the German forces was based on territorial divisions corresponding more or less to the civil ones: thus the provinces each furnished a *corps d'armée*, the districts a brigade, and the circles or parishes a battalion. Every German was liable for service, no substitution was permitted, and persons unfit to serve under arms were allotted to the non-combatant branches as hospital attendants, military tradesmen, &c. Liability to army service lasted 12 yrs., of which 3 were passed in the standing army, 4 in the reserve, and 5 in the Landwehr. In case of invasion, the Landsturm, or entire able-bodied population (up to the age of 42), could, in addition, be called to arms. To alleviate the burden of compulsory enrolment, a system of liberal exemptions was organised; the bulk of the men passed over, forming what was called the Ersatz Reserve. The army in peace time was thus composed of four distinct classes:— German army.

1. The standing army; or the men actually in the ranks.

2. The reserves; or men who had passed through the ranks and were liable to be re-called at once to the colours, and bring up the army to its war strength.

3. The Landwehr; or men who had passed through both army and reserve—who were separately organised in Landwehr battalions, and constituted a 2nd line of defence.

4. The Ersatz Reserve; or untrained men who could be called into the depôts when required.

An intimate connection was maintained between the line and the Landwehr; to each three-battalion regiment of the standing army there being attached a Landwehr regiment of two battalions. A German passed the first 3 yrs. of his service in the regular army; he then returned to civil life, but was borne on the books of the regiment as a *reservist* for the next 4 yrs.; after which period he was transferred to the ranks of the corresponding Landwehr battalion. The address of each man was registered, and at the order to mobilise he was required at once under heavy penalties to present himself at the nearest military centre, for the purpose of taking his place in the ranks. Every civilian knew exactly the position he would have to fill if suddenly called upon. By maintaining an efficient organisation at all the military centres, it was apparent that an order to mobilise could be rapidly passed on from the Head-Quarters at Berlin through all the several grades of territorial divisions till it finally reached every able-bodied man liable for service in the country. At each of the local centres, stores of clothing and *matériel* were kept ready for issue. Equally complete arrangements with regard to the mustering of horses, the formation of trains, the collection of supplies, combined with a detailed transit organisation, enabled each army corps to be assembled completely armed and equipped and ready to take the field within a few days after instructions had been telegraphed throughout the country. As a result of this almost perfect system, the army of the North German Confederation, combined with those of the affiliated states, was enabled to reach the gigantic total of 1,180,000 men within a fortnight after the outbreak of hostilities.

French army.

The French army was organised on a very different method, there being no regular peace formation of the higher tactical units. The country was certainly divided into a number of commands; but these, with the exception of the army corps at Paris and Lyons, formed territorial and not tactical combinations of troops. On declaration of war, the staff of the army was chosen and the regiments apportioned to each corps, but necessarily the component units of so disunited a mass could not work together at first without a great deal of friction. In 1866 it was apparent that, owing to many causes—the principal of which were the longer service in the ranks, exemptions by payment, and the "plague of substitutes"—the Imperial army was vastly inferior, both in numbers and *morale*, to that of Germany. To remedy this state of things the recruiting law of 1868 initiated a system of trained reserves, abolished exemption by payment, and provided for the formation of Gardes Mobiles—corresponding somewhat to a combination of the German Landwehr and Ersatz Reserve. By making the Act partially retrospective it was hoped that large additions could be at once made to the defensive forces of the country, but the premature declaration of war prevented these reforms being carried out in their entirety. On the 1st August, the total of the available troops, including many partially-trained men, amounted to 567,000. After making the necessary deductions, the utmost field force that could be assembled consisted of 300,000 men with 924 guns, and behind these in second line there were no trained reserves. In addition to numerical inferiority, the general condition of the French army was by no means satisfactory. The general officers had no experience in the leading of large bodies of troops, the staff was inefficiently educated, the regimental officers had not sufficient authority over their men, the mass of the soldiery were contaminated by the evils of substitution, and the bonds of discipline were relaxed, owing to the enervating effects of the Algerian and Mexican campaigns and the pernicious spread of democratic principles among all ranks. To rapidly mobilise the army was a matter of some difficulty, owing to the excessive over-centralisation of the administration. Every matter of petty detail had to be referred to the Paris War Office, and the machinery capable of control in time of peace was utterly unable to cope with the exigencies of war. Whereas in Germany the men of the reserves joined at once their local corps, in France the *reservist* was sent first to the depôt companies, however distant they might be, to receive his equipment, and then hurried back to his regiment, which in many cases was close to his home. The system of mobilisation was not sufficiently elastic for modern war requirements, and the first days after the declaration of hostilities, which should have been employed in the general interest of the army, were frittered away in dealing with minor administrative details. To the German system of decentralisation of large localised units, was opposed an excessively concentrated machinery working a mass of petty isolated elements.

Plans of campaign.

The Prussians, fully aware of their superiority in numbers, determined from the first to anticipate any attempt of their adversaries to carry the war on to German soil. It was obvious that if the French took the initiative they would be forced, owing to the situation of the neutral

territories of Luxemburg and Switzerland, either to advance into Rhenish Prussia or cross the upper Rhine. There was no valid reason for expecting a rapid mobilisation; though, from the existence of the eastern camps and garrisons, a part of the Imperial forces might be ready to take the field in a very short time. To counteract a possible invasion over the upper or lower Rhine, and at the same time reserve the power of employing their numerically superior forces in an offensive effort, was the problem to be solved by the Prussian staff. In accordance with a pre-arranged plan, it was decided that three large armies should be assembled in the Palatinate.

If the Emperor invaded the Rhenish provinces, he would encounter the whole of the German forces; if he crossed the upper Rhine, his line of communications and further advance would be seriously imperilled by the presence of powerful hostile bodies on his flank. To make full use of their railway sytem for rapid concentration, the French would presumedly be obliged to assemble in two main groups at Metz and Strassburg, with the Vosges separating them. In the Palatinate the Germans would stand on interior lines to masses thus formed, and be able to act against either or both simultaneously. If the Emperor massed his forces for a defensive effort, it was evident that Alsace would have to be evacuated, as the advance of the troops of the Confederation on both sides of the Vosges completely turned the first defensive line formed by that mountain chain. In this case a wheel to the right of the three armies would be necessary, preparatory to a general advance westward against the Imperial forces.

But little danger was to be apprehended from the separation of the German forces by the Vosges. If the armies on either side of the mountains were defeated, they would fall back on their own troops; while the French forces, in case of disaster, acting from divergent bases, would naturally be driven away from one another. The sole remaining difficulty was as to whether the German armies could be concentrated beyond the Rhine in the Palatinate without encountering the risk of being beaten in detail by a rapid offensive movement of the French. The plan of campaign projected by the Emperor was to mass 150,000 men at Metz, 100,000 at Strasburg, and 50,000 at Chalons as a reserve. The two first-mentioned fractions were to amalgamate, cross the Rhine at Maxau, force the southern German states into neutrality, and advance towards the Main to seek a general action with the Prussian forces. To carry out this idea it was obvious that the passage of the Rhine would have to be effected before the German armies were mobilised. Assuming this was possible, it is difficult to see how further successes were to be obtained. To force South Germany into quiescence, and at the same time mask the line of Rhine fortresses, would absorb a large proportion of the invading troops. With a line of powerful fortified cities in rear, a large entrenched camp on the flank (Mainz), and a numerically superior army in front, the prospect of a successful advance to Berlin seems somewhat visionary.

French plans.

To carry out their preconceived plans, the armies of the two nations were gradually assembled on the frontier. The order to mobilise the North German forces was issued on the evening of the 15th July, for

Concentration.

both the line and Landwehr *simultaneously;* it being apparent that the coming struggle would in all probability assume gigantic proportions. Within ten days the local mobilisations of the army corps were complete, and on the 23rd the transport by rail to the frontier commenced. Precise details as to the way in which each corps was to be forwarded—including the very hours of departure and arrival, and the number of carriages in each train—had been prepared long beforehand, and on the 30th July the German forces, divided into three large armies, took up with their leading troops the line of the Rhine from Coblenz to Germershiem.

Commander.	*Numbers.*	*Position on 31st July.*
I. Army.—General Steinmetz.	VII. and VIII. Corps, 50,000 inf., 4,800 cav.	Trevès.
II. Army.—Prince Frederick Charles.	III., IV., IX., X., and XII. Corps, and Gd. 152,000 inf., 22,200 cav.	Mayence, & S.W. of it.
III. Army.—Crown Prince.	V., XI., I. Bav. and II. Bav. Corps, Baden Div., and Wurtemburg Div. 126,000 inf., 14,800 cav.	Landau.
Total	328,000 inf., 41,800 cav., with 1,206 guns.	

The I. Corps joined the I. Army, the II. Corps the II. Army, and the VI. Corps the III. Army a few days later, forming with the addition of the 17th Inf. and four Landwehr divisions, a total of 462,000 inf., 56,800 cav., and 1584 guns.*

The French forces at this period consisted of 210,000 men,† divided into three main groups in the neighbourhood of St. Avold, Strassburg, and Chalons. Though nominally one army, it was practically two, the right wing of which (47,000 men) was east of the Vosges, under the command of Marshal Macmahon, while the left (128,000) was superintended by the Emperor personally at St. Avold. The seven corps comprised in these totals were bivouacked in a very dispersed order, and echelonned along the whole frontier, from Thionville to Strassburg. Besides these troops, there was a reserve corps of about 35,000 men, chiefly at Chalons. It must be remembered, however, that the French numbers were increasing daily, owing to the constant influx of the reserves, and at the commencement of August the strength may be put down at from 260 to 270,000 men.‡

* The German corps consisted on an average of 25 battalions, 8 squadrons, and 15 batteries, and including the cavalry divisions may be valued at 30,000 combatants. Officers and non-combatants not included in above totals.

† Strength of French army the 29th July:—

Guard (Bourbaki)	20,500
1st Corps (Macmahon)	37,000
2nd " (Frossard)	23,430
3rd " (Bazaine)	35,800
4th " (Ladmirault)	26,000
5th " (De Failly)	23,000
6th " (Canrobert)	29,900
7th " (Douay)	9,900
Reserve Cavalry and Engineers	4,550
Total	210,080 men.

‡ *Vide* Map 1 for positions on 31st July.

The difference between the two systems of concentration is strikingly apparent. Each German army corps, completely furnished with men, horses, and equipment, in its own local district, was forwarded to the front an effective unit of the army of which it was to compose a part. On the other hand, the French corps were actually mobilised on the frontier.

Difficulties first arose about calling in the reserves, afterwards in their transport and equipment, and the events of each succeeding day accumulated evidence as to the state of insufficient preparation and the other evils inherent in the French system. The railways were blocked with trains of *reservists* unable to get forward, the regimental and corps transport was incomplete, horses had to be taken from the artillery to bring forward the necessary food supplies, and the actual necessaries of bread and meat were in many cases not forthcoming. In addition to the failure of the field administration, it was found that the fortresses were in a most defective condition. Around Metz, the detached forts were neither revetted nor armed, the depôts for provisions had not been filled, nor any arrangements made for standing a siege. Strassburg and the minor fortresses fared but little better; armed with obsolete weapons, and deficient in men and stores, the energies of their Commandants were taxed to the uttermost.

Veiled by a thin cordon of outposts, the Germans formed their armies on the bank of the Rhine, and pushed forward, strong, compact, united, to the frontier; while in front of them, sprinkled along the whole line, stood detached French corps, weak in men, deficient in equipment, and swayed to and fro by contradictory orders.

Commencement of hostilities.

Up to the 2nd August there was no serious fighting on either side, but on that date the Emperor determined to make a reconnaissance in force towards Saarbrücken, with the left wing of the army. From lack of preparation, his plan was not carried out in its entirety, but resulted in an offensive movement of the 2nd Corps (Frossard) alone. Neither the I. or II. German armies having yet received the orders to advance to the frontier, the defence of the town was left to a few outpost troops, who made a gallant stand but were naturally obliged to evacuate their position. The capture of Saarbrücken, to effect which an entire French army corps was deployed in battle order, was therefore but a trifling success. It is difficult to see what object was gained by this military demonstration, as no further offensive movement was made, and the French forces remained in quietude on the banks of the Saar. Great uncertainty as to the military situation appeared at this period to exist on the French side as to whether their strategy should be of an offensive or defensive character, and even at this early stage their movements seem regulated by those of their opponents.

Combat at Saarbrücken, 2nd Aug.

In the beginning of August, Marshal Macmahon, in obedience to orders from Head-Quarters, pushed forward his troops to northern Alsace, directing his main forces towards a chosen position at Frœschwiller and sending a division under General Douay to the ancient fortress of Weissemburg.

Advance of the III. German army across frontier.

On the German side, all ideas of defensive measures had been abandoned, and the armies were gradually deploying into an east and west line, preparatory to forcing the frontier. It was evident that the

III. Army would have the arduous task of passing through the mountain roads of the lower Vosges, and eventually have to force the defiles of the main range. To allow sufficient time for this extra work, the army of the Crown Prince was put into motion on the 4th August, with orders to advance into Alsace, and the bulk of the army marched accordingly in four columns to the Lauter stream, which formed the frontier line. On arriving at Weissemburg, it was found that the town and a line of hills south of it was held by the troops of Douay's division, about 5000 in number. The old fortress was speedily captured, and a general frontal attack made on the defensive position held by the French General. The gradually advancing German forces reinforced the assaulting troops, and enabled a flank movement to be directed against the right of the French line. Completely outnumbered, after a stubborn and gallant resistance, the French gave way, and retired precipitately on their main body, then assembling in the neighbourhood of Wörth.

Action at Weissemburg, 4th Aug.

The baneful effect of the undue dissemination of forces is here painfully exemplified. The detachment of General Douay's small division to the frontier must be looked on as a strategical error. If the German forces were making an inroad into Alsace, it was clear that 5000 men could not stop them; if, on the other hand, the French troops were employed merely as an advanced post, their *rôle* should have been more clearly pointed out to them.

Advance of III. army, Weissemburg to Wörth.

On the evening of the 4th all contact with the enemy was lost, and the next day, in rear of large bodies of reconnoitring cavalry, the III. Army advanced, prepared to concentrate for battle in either a southerly or westerly direction. Information was received on the 5th that the French were assembling in force in the neighbourhood of Wörth, with the evident intention of disputing the passes of the Vosges, and orders were issued in consequence for a concentrated advance in that direction.

On the French side confusion reigned supreme. Owing to the defective and tardy concentration, the original plan of campaign could not be carried out. Reduced to defensive measures by the threatening advance of the German forces, it was obvious that a general union of the dispersed corps would be advisable. It was clearly impossible for the left wing of the army to advance through the Vosges and leave the I. and II. German Armies on its flank. If, however, the French right wing was to retire westward, the whole of Alsace would be given up without a general engagement—a proceeding likely to be received with little favour by the turbulent spirits in the capital. The independent command of the right wing was accordingly bestowed on Macmahon, with the clear understanding that he should endeavour to make head against the invader. Telegraphing to the corps of De Failly at Bitsch, which had been placed under his orders, and hurrying up available troops from Strassburg, were the measures he adopted preparatory to taking up at Wörth a tactically strong position, which defended, both directly and indirectly, the main passes through the mountains.

Battle of Wörth:—Fr. 45,000 Gr. 130,000

The French troops facing east (left wing retired), occupied a line about $3\frac{1}{2}$ miles in extent along the undulating, partly wooded, partly vine-clad spurs of the western Vosges. In front, within musketry range, was a valley of flat meadow land traversed by the Sauer—a stream fordable with difficulty in consequence of recent rains. The

range of heights on the eastern side of the valley afforded but little shelter to an advancing force, the right flank was open and could be swept with artillery fire, but the existence of wooded ravines rendered a refusal of the left necessary. A main *chaussée*, running at right angles to the defensive line, passed through the villages of Wörth on the Sauer and Frœschwiller in rear of the centre of the position.

On the morning of the 6th the leading troops of the III. Army came in contact with the French outposts, and attacked impetuously. On neither side was it intended to fight a general action, but the serious engagement initiated by the German advanced guards rendered a withdrawal from the fight rather compromising. Up to mid-day isolated attacks attended with great loss were made against the position, finally culminating in an artillery duel between the batteries of both armies. Supported by the concentrated fire of their massed artillery, and the hourly increasing numbers of their troops, the V. and XI. German Corps made a general advance against the French right and centre. The fire-swept low-lying meadows were traversed with heavy loss, and a footing gradually gained on the western side of the valley. The central attack made but slow progress, but ground was gradually gained in the Niederwald—a wood on the French right—and a portion of the Imperial troops were cut off and retreated in disorder towards Haguenau. The attacking line gradually converged towards Frœschwiller—the key of the position—the great superiority in numbers of the Germans leading to the gradual envelopment of the French flanks. Heroic attempts were made to change the fortunes of the day by charges of cavalry; but the nature of the ground was too unfavorable to admit of the slightest success. Overmatched in artillery and completely outnumbered, the French at last gave way, and fled to the rear in the greatest confusion. Some of the fugitives took the road to Bitsch, many made their way to Strassburg, but the bulk of the army retreated to Saverne, where they were eventually reduced to a semblance of order. Owing to the impossibility of pushing unsupported cavalry through the mountain passes, and the rapid forced marches of Macmahon, all contact between the two armies was lost. The 7th was a day of rest for the German forces, with the exception of the Baden Division, which was sent off in the direction of Strassburg, which was summoned to surrender on the 9th August.* 6th Aug.

Suddenly given command of an army dispersed along the frontier from Bitsch to Strassburg, with an enemy of threefold strength within a day's march, the position of Macmahon was certainly unenviable. Exception may, however, be fairly taken to his stand at Wörth; though tactically strong, the position was strategically defective. For an inferior force to offer battle with a series of defiles in its rear cannot but lead to disaster in case of retreat, and to defend the passes of the Vosges in such a manner when they were practically turned by the advancing I. and II. German Armies seems injudicious. If from political causes it was necessary to fight east of the Vosges, it would appear that the retention of Strassburg as a base would give the opportunity of striking an offensive blow on the flank of an army attempting to cross the moun-

* The siege of Strassburg is referred to subsequently.

tains, and at the same time secure a safe retreat. The non-appearance of De Failly's corps on the field has been the subject of much comment, arising as it did from the reception of contradictory orders from the Head-Quarters of each wing of the army. Although the defeated troops were much disorganised, it seems scarcely necessary for them to have taken such a circuitous route westward, or retreat so far. It has been suggested that a better course would have been to gain Metz by the left bank of the Moselle and join the forces of Bazaine, or retreat southward on Belfort. In the one case the union of the entire French army would be effected, in the other the presence of regular troops in the south would undoubtedly compel a division of the German forces, and possibly arrest the general advance.

Advance of the I. and II. German armies. Aug. 5th and 6th.

In the meantime, the I. and II. German Armies advanced side by side to the frontier. Acquainted with the success of the III. Army and suspecting a retreat of the French forces in their front, they pushed forward their advanced guards towards Saarbrücken and the line of the Saar. It was intended that the main body of the II. Army should pass through the town while the I. Army was utilising points of passage lower down the river.

Battle of Spicheren: Fr. 32,000 Gr. 67,000

On the 6th August, General Frossard (the Commandant of the corps that made the demonstration on the 2nd), withdrawing his outposts, took up a position on the Spicheren-Steiring heights, opposite the town of Saarbrücken. Deceived by the apparent retreat of the French, and under the impression that a weak rear guard had alone to be dealt with, the leading German troops boldly crossed the river. A heavy fire of artillery, however, soon made it apparent that the nearly impregnable heights were held in force. In spite of great inferiority in numbers, a bold attack was made on both flanks of the position, but without success; and the small German force (a division), fought unsupported against the whole of Frossard's corps for more than two hours. Gradually accruing reinforcements gave a new impetus to the attack, which became general along the whole line. The steep slopes of the plateau were gradually surmounted, in spite of the murderous fire of the Chassepôt, and with incredible exertions twelve guns were eventually hauled up to the crest. As at Wörth, a wood on the right of the French line was successfully utilised in the advance, and the superior direction of the German artillery plainly evinced. Against the Prussian position on the edge of the plateau, frontal attacks in force were repeatedly made. Disheartened by their want of success, and threatened on their left flank by newly arriving troops, the French gave way at nightfall and retreated in good order on Saargemund.

It is not difficult to attribute to its true causes the double defeat suffered by the French on this day. Superiority in numbers and organisation, combined with the advantage of taking the offensive, were on the German side. The advance of their powerful armies on both sides of the Vosges, with their flanks covered by Luxemburg and the Rhine, was a safe operation; and though either wing might have received a check, a disaster was impossible. On the French side a defective administration nullified all the attempts to carry out the original plans of the Emperor. The disposition of the several corps seems, moreover, very injudicious,

and to violate the sound principle that inferior forces should be massed. Whether for offensive or defensive purposes, it was essential that the French troops should be concentrated; and while effecting that object it was unsafe to place isolated corps, liable to defeat, so close to the frontier. Distributed, however, as they were, the lack of common reconnoitring precautions seems inexcusable. In the several engagements—notably at Spicheren—the want of mutual co-operation of corps on the French side is especially remarkable, while the sound of firing apparently hurried all available German forces to the field of battle. This principle seems, however, to have been carried to excess at Wörth, where the German outflanking troops lost sight of their proper objective.

Retreat of French.

After their defeats, the beaten armies retreated in an easterly direction in two large masses. The greater portion of one of these bodies consisted of the troops routed at Wörth, whose retirement was compulsory and attended with disaster. The left wing, on the other hand, was composed of the main Imperial army, only one of whose corps had yet been in contact with the enemy. With their right wing utterly disorganised, and their main body threatened in front with superior numbers, it was obvious that all offensive action was impossible, and that immediate measures had to be taken to secure the defence of the country. To effectually utilise their inferior forces, it was necessary to unite the two separated portions (now bearing the names of the armies of Chalons and Metz). Owing to the disorganised state of Macmahon's troops, it was hopeless to expect a concentration east of the Moselle, and a general retreat to that river was ordered. There was much dispute as to the best course to pursue—whether to retire direct on Chalons, and thereby unite the two armies; or to retreat on Metz with the main body, and endeavour to close in the right wing to it; or to take up a defensive position south of Metz, and dispute the passage of the Moselle. As a consequence, between the 6th and 12th of August, orders and counter-orders succeeded one another with lamentable rapidity; but eventually the retreat on Chalons was definitely decided on. The main body retired from the district of St. Avold directly on Metz, the vicinity of which was reached on the 12th inst. The 6th Corps (originally a portion of the reserve), was hurried up to the fortress, and on the 13th an army of 176,000 men was assembled under the detached forts lying to the east of Metz. Macmahon, in the meantime, was retreating *viâ* Luneville on Chalons, where he eventually* succeeded in collecting about 120,000 men, the greater portion of whom consisted of the 1st, 5th, and 7th Corps.

6th–13th Aug.

While the two armies were in full retreat, strenuous efforts were made by the Government to increase the defensive power of the country. The Gardes Mobiles were called out throughout the whole of France, old soldiers were recalled to the ranks, the troops destined for the Baltic expedition (including marines), were hurried to the capital, and provisions laid in with the utmost despatch.

Whether it was necessary to give up the whole of the country east of the Moselle without resistance is a matter for discussion, but under the circumstances it was probably advisable. The defensive positions on the Nied were not suitable for an army so large as that of Bazaine, and

* 21st August.

the co-operation of Macmahon could, moreover, scarcely be expected. At Frouard, however, on the Moselle, both armies might easily have been concentrated by the 13th, and the position would have been both strategically and tactically powerful. On the other hand, the fortress of Metz was in a most defenceless state, and urgent appeals were made to secure its safety by the detachment of a large force. By marching the troops of Bazaine through the town, time and opportunity would be given for strengthening the works and reinforcing the garrison of the virgin city.

Advance of the German armies.

After their successes at Wörth and Spicheren, the three German armies occupied with their leading troops a south-easterly line passing through the two places, the III. Army (Crown Prince) being separated from the other two by the mountain chain of the Vosges. Owing to the hurried retreat of the French forces, contact was lost for the time; but it was naturally supposed that a serious stand would be made on the line of the Moselle. To effectually link the armies together and make a simultaneous advance towards the retreating troops, it was necessary to make a strategical wheel to the right on the pivot of Saarbrücken. To carry out this measure the I. Army (Steinmetz) had to remain halted, the II. (Prince Frederick Charles), gathering up its rearmost troops, had to push forward south to form the centre of the line, while the III. (Crown Prince), forming the outer flank, had to traverse the difficult defiles of the Vosges, and close in on to the left of the II. Army. The passes through the mountains which the Crown Prince had to utilise were closed by small forts, none of which proved a real obstacle with the exception of Bitsch and Phalsbourg.* Advancing in five different columns, the mountain range was crossed in two days, and union with the left of the II. Army effected on the line of the Saar. As soon as the wheel was completed, the three armies marched westward through Lorraine, linked together in one homogeneous body, with their front covered by a numerous cavalry, two days' march ahead. On the 12th August the positions marked in the map were reached, the right of the whole force resting on the Nied, the left somewhat withdrawn at Saarburg.

8th Aug.

Map 2.

12th–14th Aug.

The same evening the French Emperor, constrained by public opinion, handed over the command to Bazaine, with definite instructions to retreat at once through Metz on Chalons. Numerous temporary bridges had been previously thrown across the Moselle, but were rendered useless for the most part on account of heavy floods. The whole of the 13th was occupied in arranging the details of a passage, which was not commenced till the following morning. The French troops were encamped on the right bank of the river in a wide semicircle, within range of the detached forts. The cavalry patrols sent out in the morning did not report the presence of an enemy, and the retreat was leisurely begun from both flanks of the line of bivouacs. By 3 o'clock half the French forces had crossed the river.

14th Aug.

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* Bitsch—a strong isolated fort—was invested by Bavarian troops, and did not fall into German hands during the war.

Phalsbourg, commanding the high road through the Vosges, was bombarded by the XI. Corps and eventually invested by Landwehr troops. The Commandant made a most gallant resistance with the small garrison at his disposal (1200 men), and held the fort up to the 12th December, when famine forced him to capitulate.

In the meantime, the three German armies, steadily advancing, had reached with their advanced troops the vicinity of Metz and the general line of the Moselle.

Battle of Borny:—Fr. 104,000 Gr. 98,000

The General commanding the advanced guard of the VII. Corps (I. Army) arriving at Laquenay, saw the French troops gradually defiling to the rear. Aware that it was highly important that the French retreat should be delayed as much as possible, in view of the contingency that a flank attack might be made on the leading troops of the II. Army now crossing the Moselle, he determined to assault at once with the small force at his command (a brigade), informing at the time the commanders of the corps nearest him (the I., VII., and IX.) of his intention. Covering the French retreat was the 3rd Corps (Decaen), deployed in two lines facing to the east on the heights above the village and valley of Colombey. These troops were in the act of retiring when attacked impetuously on their centre by the brigade Goltz. On the German side were advancing in support the leading troops of the I. and VII. Corps, on the outer flanks of which were two cavalry divisions. The gradual reinforcement of the fighting line eventually converted into a battle what was originally but a vanguard action. To meet the increasing hostile forces, a portion of the French 4th Corps (Ladmirault), which had crossed the river, was repassed to the right bank, and in conjunction with the troops of Decaen resisted the German advance with success. The Imperial Guard was available for offensive purposes, but was employed solely as a reserve. As night closed neither side had given way, and in accordance with the orders of the morning the French retreat was continued, and the remainder of the army passed across the river under the protection of the detached forts.

This battle—commenced at an hour at which engagements often terminate—may be cited as a successful example of an advanced guard action, where a small body of troops initiated a strategical victory by arresting the retreat of an army, maintaining at the same time, without retiring, the forward position to which a bold attack had committed them. Victory has been claimed by both sides, and tactically it may fairly be considered to be a drawn fight. The strategical importance of the engagement was, however, clearly seen by the German Head-Quarters, as evinced by the order issued on the morning of the 15th:—"The fruits of the victory (*i.e.* Borny) can only be gained by a vigorous offensive by the II. Army towards the Metz-Verdun Road (east of Metz)." The attack of General Goltz with his advanced guard brigade was certainly justified by its success, but it is an open question whether in case of failure it would not have incurred much hostile criticism. The conduct of Bazaine at this period has been much commented on. It has been urged that if he was bent on retreating, he should not have fought at all on the 14th, but let the guns of the Metz forts keep the enemy at a distance; or if he accepted battle, he should have taken a vigorous offensive against the inferior forces in his front. On the other hand, he has stated as his opinion that he was committed to a retreat, but that the outer detached forts were in such a defenceless state that they were liable to be taken by assault, and that therefore the onward pressure of the Germans had to be resisted up to a certain point.

15th Aug.

On the following day the march westward of the French was continued.

From Metz two main *chaussées* lead towards Verdun—the northern passing through Woippy, St. Privat, and Briey, the southern through Longeville to Gravelotte, where the road bifurcates. It was intended that the retreat should take place by the southern of these roads as far as Gravelotte, and thence by the *chaussées* leading through Doncourt—Conflans and Rezonville—Mars-la-Tour. On the Rezonville Road the 2nd Corps (Frossard) was to lead, followed by the 6th (Canrobert) and the Guard; on the more northern route the 4th Corps (Ladmirault), followed by the 3rd (Lebœuf),* which was again to act as rear guard in anticipation of an attack from the north of Metz by the I. Army. Great delay was caused in passing through Metz, owing to the encumbrance of quantities of unnecessary baggage,† and the insufficient bridging of the Moselle. Some additional time was also undoubtedly lost on account of the action of Borny. The troops on the most southern road were ready to advance, but were obliged to wait until the rest of the forces had reached their assigned positions. On the evening of the 15th, the 2nd and 6th Corps were bivouacked in the neighbourhood of Rezonville, the Guard being to their rear on the Gravelotte plateau. During the day the presence of German cavalry and artillery on the left flank made itself apparent, but the importance of the fact does not appear to have suggested itself to the French staff. Aware that Bazaine was in full retreat, the German II. Army pushed forward with alacrity in the direction of Verdun, in order to intercept him. It was necessary to keep some troops on the eastern side of Metz, to prevent sallies of the garrison—a duty which naturally fell to the I. Army, which was already in position.

Map 3. On the evening of the 15th, the II. German Army had four of its corps‡ on the line of the Moselle (Metz to Frouard), one division having reached the advanced position of Thiancourt. Further south, the general line of advance was taken up by the troops of the III. Army.

16th Aug., Rezonville: Fr. 135,000 Gr. 95,000 The French retreat was to have been resumed at 4 a.m., but owing to the 4th Corps not having come up into line was deferred till midday. Early in the morning a reconnaissance in force was made by the 5th (German) Cavalry Division, and four batteries of horse artillery. Advancing at a gallop, the batteries unlimbered on a hill south-west of Vionville, and rapidly shelled the French cavalry camp to the west of that village. Taken completely by surprise, the French squadrons galloped to the rear in complete disorder, and eventually re-formed behind the line of their infantry bivouacs at Rezonville. More to the eastward, from the direction of Gorze, the 6th Cavalry Division now drove in the outposts in front of them, and completed the arc of observation. Against the wide circle of cavalry, extending from the Bois de St. Arnould to the Tronville heights, the French infantry advanced to attack in lines radiating from the centre—Rezonville. At 10 o'clock, at the extremeties of the cavalry arc, the first Prussian infantry appeared on

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* General Decaen was mortally wounded at Borny.

† Accompanied by large trains of personal baggage, luxurious mess equipages, and crowds of servants and adventurers, the army of Bazaine has with some severity been entitled the army of Darius.

‡ The III., X., IX., and IV.

the ground—the 5th and 6th Divisions of the III. Corps. An immediate advance was made by these troops, and the villages of Flavigny and Vionville captured with heavy loss. At noon the French, acting generally on the defensive, occupied the heights west of Rezonville with two corps facing westward. Bazaine, apprehensive of being cut off from Metz, kept his reserves on the Gravelotte plateau. The French right (3rd and 4th Corps) were moving southward towards the line of battle. It will be seen that one German corps, preceded by two cavalry divisions, had thus placed themselves across the road in front of the whole French army. At 2 p.m. the French 3rd Corps came into action, aud it was apparent that an advance was about to be made by the right of the French line. In order to effect delay, and give time for reinforcements to come up, a brigade of German cavalry was launched against the threatening troops, and their daring charge, in spite of enormous loss, effected its object. At 3 o'clock, the X. Corps arrived in time to reinforce the threatened German left, and about the same time the French right was increased by the addition of the 4th Corps. The line of battle, which formerly stood nearly west, now faced due south. A series of attacks with varying success were made by the newly arriving French troops, and finally led to a great cavalry engagement in the vicinity of Mars-la-Tour, for which both nations claim success. On the other side of the battle-field a desultory fight was kept up as long as daylight lasted. The losses of the contending forces were very heavy—amounting on each side to about 16,000 men.

The true importance of this day cannot be judged of by its tactical results. The Prussians had certainly not been able to drive the French out of their main positions; but, on the other hand, the French had not been able to recover the ground lost before noon, nor re-continue their march. The victory, however, clearly lay with the Germans in a strategical point of view. By a bold employment of their numerically inferior forces they had stopped the French retreat, and given time for their main body to effectually interpose between the junction of the two Marshals. Much criticism has been expended on the unnecessary delay under the eastern forts of Metz, and the time occupied in crossing the Moselle. It is difficult to understand why the northern route by Briey was not utilised. Every moment was of consequence, and to endeavour to march the greater part of a large army by one road out of Metz could only lead to great loss of time. There appears to have been an idea that an attack would be made to the northward by troops crossing the Moselle lower down than Metz. At the same time, it was well known that the bulk of the II. Army was approaching the line of the Moselle above Metz, and common precaution might have suggested the destruction of the permanent bridges at Ars and Pont-à-Mousson. Bazaine (who took over the command of the army on the evening of the 12th) did not apparently realise the necessity of a retreat westward, but was more inclined to rest on Metz as a base from which offensive operations might be directed. This view was perhaps not unnatural, particularly when the weak state of the detached forts was considered; but still it was against the spirit of the orders he had received, and militated against their being effectively carried out. The French forces were considerably inferior in numbers to those of their adversaries, and their best hope of

success lay in a retreat for the purpose of combination. It is difficult to see why the fatal delay in marching off was permitted. Assuming that the previous loss of time was unavoidable, the reason for a further stoppage seems insufficient. The presence of the German cavalry was well known, and if an uninterrupted retreat was desirable, every moment was of value. Admitting that the 4th Corps was late in its appearance, this defeat might still have been partially obviated by directing it to act as a rear guard on the more direct southern road, while the Guard could have been shifted to the more northern *chaussée*. When committed to the engagement at Rezonville, why was a continuous defensive so sedulously maintained? The German troops, if attacked with the vigour naturally in accord with the French spirit, during the morning must have been defeated. Even in the afternoon, when their reinforcements came up, they were numerically much inferior to the troops of the Marshal. The bulk of the German forces were in the act of crossing the Moselle, and a vigorous effort directed southward must have driven back their leading troops in confusion, and possibly allowed the army to pursue its retreat. A defensive line was, however, taken up instead, and the reserves kept on the left flank. Bazaine allows himself that he was afraid of being cut off from Metz; but that surely cannot be admitted as a valid plea. His orders were to retreat on Verdun, and in natural concurrence with this would be a departure from Metz. The fear of leaving the fortress which he avowedly shows, demonstrates how completely he failed to realise the exigencies of the strategical situation. With regard to the bold attack of the III. German Corps, it may be fairly questioned—despite most of the German accounts—whether its commander was at all aware of his having the whole French army in front of him. Throughout the battle the Germans laid themselves open to be beaten in detail, and that they were not so must be attributed more to the inaction of the French Marshal than to any tactical combination of their own.

17th Aug. On the night of the 16th both armies bivouacked on the field of battle, but at daybreak the French forces retired according to orders towards Metz—the retrograde movement being adopted ostensibly on the ground of want of ammunition and food supplies. The army eventually took up a position on the continuous chain of heights to the east of and overlooking the Manse rivulet (extending from Rozerieulles to St. Privat la Montagne). On the evening of the 16th orders were issued for the concentration of the II. Army on the battle-field. The III. and X. Corps, and a portion of the VIII. and IX. were already on the ground. There was little danger to be apprehended from a sortie from the fortress to the south or east, so the VII. and VIII. Corps of the I. Army were ordered to cross the river and form with the IX. the right of the bivouacked troops. The XII. Corps and Guards were directed northward to the left of the line in the neighbourhood of Mars-la-Tour. The I. Corps was left as a precautionary measure on the right bank of the river, and the II. Corps, which was somewhat in rear, hurried forward to Pont-à-Mousson.

18th Aug., Battle of Gravelotte: Fr. 130,000 Gr. 230,000 There was some uncertainty at the German Head-Quarters as to whether the French intended to attempt pursuing their retreat by a more northerly route, or offering a defensive battle under the forts of

Metz. Equally prepared for either contingency, the order was given for an advance in echelon of corps from the left in a northerly direction, the XII. Corps leading, followed by the Guards and IX. Corps, the X. and III. Corps following in 2nd line. The VIII. Corps was to move on the right rear of the IX., and the VII. still further to the right, forming the pivot in the case that a wheel to the right towards Metz should be necessary.

The French position extended for 7 miles along the crest of an open and broad ridge, the western slope of which mostly fell with a gentle declivity. The left wing was very strongly posted, owing to the nature of the ground and the protection afforded by the fort of St. Quentin and the Moselle valley. The right wing rested on no natural or artificial obstacle, and but few temporary arrangements were made for its protection, owing to the absence of engineering tools. The reserve was posted in rear of the left wing. Map 4.

As the German echelonned corps marched northward, covered by their cavalry scouts, it soon became apparent that the French had delayed their retreat and taken up a defensive position resting on Metz. Orders were accordingly issued to move up into line in order to attack, it being intended that the two leading corps (the XII. and Guards) should envelope the French right flank. The simultaneous assault on the whole of the front line was prevented principally from a misconception as to the limit to which the French defensive position extended, and the battle was commenced at mid-day by the artillery of the IX. Corps. In order to afford support, the VII. and VIII. German Corps advanced against the left of the French line, while the left wing of the II. Army continued its steady movement onward. The artillery of the Guards by 2 p.m. came into action on the left of the IX. Corps, its infantry advancing against St. Marie aux Chênes. At 5 o'clock the French army held intact its whole main position, after a frontal attack, chiefly of artillery, had been raging for five hours without intermission. Soon after this time an advance across the gently sloping glaces of St. Privat (the right of the French line) was made by the Prussian Guard, but was repulsed with heavy loss. The XII. Corps by 6.30 o'clock eventually carried out its flank movement, and commenced the attack of St. Privat from the north. A second advance—this time successful—was made at the same moment by the Prussian Guard, and the French right was thrown back in utter confusion, just as darkness set in. Early on the 19th the beaten French troops took up their bivouacs in a concentrated position under the Metz forts.

The objective of the two armies was at this period the same—an advance towards Paris—the French for the purpose of combination, the Germans to reach their natural goal, the Capital. If Bazaine could have left a sufficient garrison in the Metz forts and have resumed his march, the double advantage would have been gained of detaining a large investing force round the fortress and uniting the two French armies. Success depended on the factor of time; and how this element was on the one side frittered away in baneful hesitation, and on the other utilised to its fullest extent, is a study replete with interest.

On the 18th August retreat westward was impossible, unless preceded by a decided success, for the obtention of which it was obviously

necessary that more than purely defensive measures should be taken. A defeat to the German forces might have been most disastrous, and it is a question whether Bazaine did not lose a valuable opportunity in not taking the offensive against the centre of the allied line. Whether it was expedient for the Germans to accept battle at all is somewhat doubtful. The interception of the French retreat was complete on the 16th, and the French General could only resume his march by becoming the assailant and laying himself open to be attacked in flank. In lieu of taking up the Amanvillers position, it has been suggested that Bazaine might have passed his troops through Metz to the right bank of the Moselle on the 17th and taken the offensive in a south-easterly direction, pushing his army towards Strassburg and cutting the German communications. That this course was possible with a well-led army has been pretty generally admitted; but it is doubtful whether under the inferior direction that signalised the warfare round Metz any such attempt could have been successful.

The position of the combatants in this battle is especially striking. Each army was facing towards its original base—the Prussians having their back to Paris, while the French faced towards it. As at Rezonville, the disposition of the French reserve seems very faulty, and to have arisen from an entire misconception of the value of the supporting fortress. If the Imperial Guard had been sent in time to the assistance of the right wing, it is very doubtful whether the turning movement of the Saxons would have resulted in success.

The retreat of Bazaine having been effectually put a stop to, the next object of the German leaders was necessarily to make innocuous the flower of the French army, so recently beaten, while a rapid advance was made against the troops of Macmahon. Orders were accordingly issued by the King, on the morning of the 19th, detailing a certain number of corps (comprising the I. Army, and the II., III., IX., and X. Corps of the II. Army), for the duty of investing Metz; while the Guards, IV., and XII. Corps were constituted into a IV. Army,* destined to operate with the already advancing III. Army against Chalons and Paris. A circle of investment about 32 miles in extent was formed outside effective range of the detached forts, and diligently strengthened by means of earthworks and obstacles. Owing to the heavy losses of the preceding days, the German corps were much reduced in numbers, and the investing force may be estimated at from 160 to 170,000 men—an effective the total of which was daily increasing, on account of the arrival of reinforcements. The army of Bazaine numbered about the same, inclusive of a large number of wounded and non-combatants.

The III. Army, in the meantime, had advanced nearly to the Meuse (south of Toul), and was awaiting the issue of the engagements about Metz. On the 19th it received orders to continue its march westward,
20th Aug. and on the 20th the main body, in four columns, protected by cavalry on the left flank, had crossed the river. Macmahon's troops, consisting of the 1st, 5th, 7th, and 12th Corps, were at this period at the camp of Chalons.

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* Called the army of the Meuse.

MAP I.

POSITION OF FRENCH AND GERMAN ARMIES ON THE 31ST JULY 1870.

German Army Corps and Divisions
French Army Corps and Divisions
Cavalry Divisions.

Length of Frontier line from Luxemburgh to Rhine 115 miles. The Vosges mountains run parallel to the Rhine at an average distance of 30 to 40 miles and extend as far north as Mannheim.

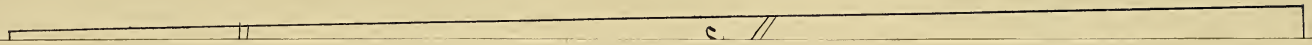
The I & II armies crossed the frontier at Saarbrucken, the III army at Weissemburg on the opposite side of the Vosges. The French left wing after the fight at Spicheren (close to Saarbrucken) retired direct on Metz.

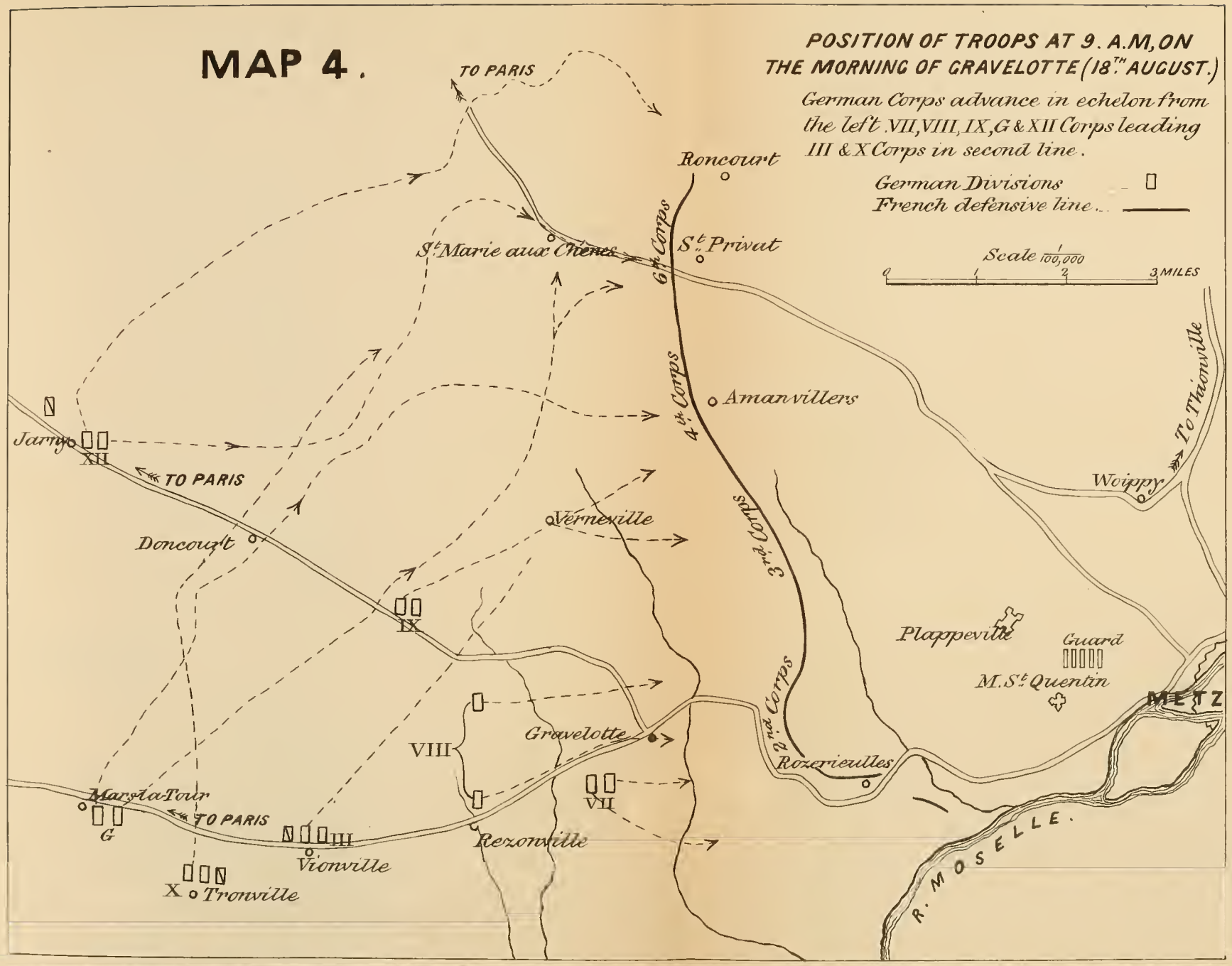
The French right wing after their defeat at Wörth retired westward through Saverne and Luneville.

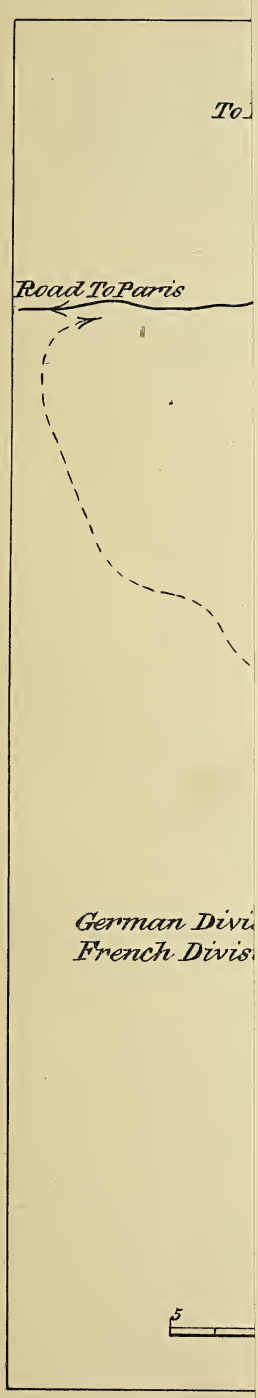
Metz to Saarbrucken _____ 37 miles.
Metz to Strassburg _____ 76 ,,
Strassburg to Wörth _____ 24 ,,

MAP. 2.

I & II ARMIES
III ARMY
FRONTIER LINE
VOSGES MOUNTAINS
R. Saar
R. RHINE
Thionville
METZ
Boulay
St Avold
Saarbrücken
Saargemund
Bitsch
Weissemburg
Wörth
Pont à Mousson
Chateau Salins
Phalsbourg
Saverne
Frouard
Nancy
Saarburg
STRASSBURG
MACMAHONS RETREAT
Luneville
THE GERMAN ADVANCE FROM
6TH TO 12TH AUGUST.
Position of Germans on 6TH
12TH
French on 12TH
SCALE 1/1,000,000
0 5 10 15 20 25 MILES




MAP 4.
POSITION OF TROOPS AT 9. A.M, ON THE MORNING OF GRAVELOTTE (18TH AUGUST.)
German Corps advance in echelon from the left. VII, VIII, IX, G & XII Corps leading III & X Corps in second line.
German Divisions
French defensive line
Scale 1/100,000
0 1 2 3 MILES
TO PARIS
Roncourt
St. Marie aux Chênes
St. Privat
6th Corps
4th Corps
3rd Corps
2nd Corps
Amanvillers
Jarny
XII
TO PARIS
Doncourt
Verneville
IX
Woippy
To Thionville
Plappeville
Guard
M. St. Quentin
METZ
Gravelotte
VIII
VII
Rozerieulles
Mars la Tour
G
TO PARIS
III
Vionville
Rezonville
X
Tronville
R. MOSELLE.


To
Road To Paris
German Divi
French Divis
5

MAP. 3.

POSITION OF FRENCH & GERMAN ARMIES EARLY ON 16TH AUGUST.

Showing direction of march of latter toward battle field of Rezonville.

The French retreating westward by roads through Doncourt and Mars-la-Tour are bivouacked on the Rezonville heights waiting for their rear-most troops to come up.

ON THE CONSIDERATIONS AFFECTING THE POSITIONS TO BE TAKEN UP, AND THE TIME OF OPENING FIRE BY ARTILLERY IN THE FIELD, UNDER THE FOLLOWING CIRCUMSTANCES:—

1. As Artillery of the Advanced Guard.
2. " Main Body of an Attacking Force.
3. " Main Body of a Defensive Force.
4. " Rear Guard.

AND ON THE RESULTS OF FIELD ARTILLERY FIRE AGAINST THE MOST RECENT FORMATIONS IN WHICH TROOPS ATTACK.

BY

COLONEL H. A. SMYTH, R.A.

[THE R.A. INSTITUTION PRIZE ESSAY OF 1876.]

"Vis consilî expers mole ruit suâ."

Rapid as has been the development of the capabilities of rifled field artillery, it has not outpaced the special literature of the subject; and there is no lack, but rather superabundance, of treatises on the peculiarities of the arm and the system of tactics most suitable for their advantageous application under the varying conditions of war. That is, as to the quantity furnished of such works; as to their quality, one great want is present in them all—a want not new in the history of the world, yet ever fresh and young, without the cancelling of which but little good can come of any theories, or judgments, or transactions—the want of a recognition of the opposite side of the question.

"Your artillery won the battle; the Prussian artillery is the best in the world," Napoleon III. is reported to have said the day after Sedan. "It is scarcely possible to accomplish more than the artillery accomplished; the many victories are owing principally to its co-operation," wrote the Russian Baron Seddeler, in his "Study of the War of 1870–1." "Nevertheless, it is certain that to the German artillery, at Sedan as well as in all the other battles and actions, is due the principal share in the destruction and subduing of the French," says the Austrian Major Rosinich. "It is by acting in accordance with these principles," (that is, the pushing forward every available gun), "and placing in line as many batteries as possible, that we have won all our victories," runs the extract* from the Prussian author

* The original, indeed, does not run quite so strong. Literally translated, it says:—

"To the circumstance that all the available batteries were brought as early as possible into the line of battle, do we mainly owe our victories; to the changed posting of the corps artillery do the

writing under the pseudonym of Robert Becker, given in Home's "Modern Tactics": and so on, many others, in the evaluation of recent actual experiences.

Then we have deductions from the same, and from the general character of the arm. Major Rosinich, even in 1867, reviewing the war of 1866, wrote:—"The pre-eminent advantage of rifled artillery consists in its affording the means of directing a concentric fire on any desired point of the line of battle." The Austrian Captain Müller wrote in 1868:—"The employment of artillery in the deciding *rôle* comes out now more prominently than heretofore; and the application of this arm, even in the sense of support and protection, will frequently bear a character little differing from that of the *deciding* action." In an essay in the Berlin "Archives for Artillery and Engineer Officers" for 1870, occurs the prophecy:—"In the next war the infantry and cavalry will probably be evenly matched; but success is assured to him who has the superiority in artillery." And the Badener Major Müller, in his important work, the "Evolution of Field Artillery," in 1873, deduces that "the future will bring with it artillery combats of vast extent and formidable almost beyond conception, and in them, under otherwise equal circumstances, the victory will fall to the more *effective* system;" and, in his conclusion, that "one is justified in taking it for certain that faults in the employment of artillery in action will either absolutely never, or at any rate very seldom, be possibly to be made up for. Once your artillery is worsted, you have small chance of a success. Neither the attack nor the defence have a prospect of attaining their end without the fullest and most powerful assistance from the artillery."

These transcendent views, moreover, base themselves in the most respectable manner on foundations established amongst the received apothegms of the past. Okounef's:—"Shrapnel must give to artillery such a destroying effect that it will decide the fate of future battles." "It will become the scourge of mankind." "The day cannot be much longer delayed when the artillery shall raise itself, from being auxiliary, to the rank of a principal arm." Prince Augustus's:—"The artillery has given" (at Gross-Görschen) "the most convincing proofs that it, when worked with steadiness and judgment, is irresistible." Napoleon's:—"The artillery constitutes now the true fate of nations and armies;" together with the decisive achievements of artillery at Gross-Beeren, Lützen, Bautzen, Friedland, Borodino, &c.— all instances of what value the arm had attained to in the old smooth-bore days— are brought forward as material only needing the new life conferred on it by rifle-power to establish for artillery a leading, an independent, a *deciding* character.

The general theory thus raised is of importance to the particular

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combined arms mainly owe the changed results."—"Die Erfolge der preussischen Feld-Artillerie in der Campagne 1870–1," p. 24.

But the extract, in the form in which it has been *set* in Major Home's précis, must be regarded as attaining to greater prominence in the literature of the day than the original sentence, which occurs only in a special and limited essay.

subject of our essay, inasmuch as a great part of the very newest teaching on the tactical employment of artillery is framed in accordance with, or breathes the same spirit as, that theory. The epitome of all its prescriptions runs very nearly :—"Establish your superiority in artillery effect as early as possible, and keep it throughout." And proof is adduced to show that such a method of determining the course of the action must save the other arms from sensible losses. The subsidiary steps to be taken (passing by the constantly recurring recommendation to "increase the field artillery"—patriotic enough, no doubt, but outside our present subject) towards this end are direct enough :—"Push forward all your artillery as far as you can, into action as early as you can; every individual gun not in position from the very beginning of the action represents, during its inaction, just so much of the means of victory unapplied." And therefore "Consider the whole of your artillery—corps as well as divisional—absolutely as advanced guard. Mass it at the very beginning, and so anticipate the enemy's developments of artillery. All the support needed at this period will be easily furnished by a few cavalry squadrons. Especially avoid that most mischievous fault of keeping any guns whatever as a reserve."*

Thus, whilst this advanced mass of artillery is shattering the dispositions of the enemy, and, as the critical points become more evident, concentrating its fire upon them, the other arms are to be brought up into the formations appropriate to the object of the action, secured from interruption, and, it may well be, even from observation, behind the screen of the artillery—which thus performs tactically, for the dispositions of the other arms, the same office that the cavalry, in its newest and highest application, has discharged as "the strategic veil" for the armies. Few technical details are necessary to this simple system. To bring as many guns as possible into one long line (which may be echelonned where the ground requires it), combining their action under one command, is the most urgent recommendation; to depend for escort on the continual arrival of the rest of the troops, and on an intimate tactical relation with them; to change position but rarely, but then effectively, and ever nearer to the object; to keep the ammunition columns well up and in effective communication with the fire-line for the supply of ammunition, men, and horses—these are the principal remaining heads of the teaching generally deduced by this school from the last war.

There have, moreover, been included with the foregoing some maxims drawn from the earlier lessons of Prince Kraft of Hohenlohe-Ingelfingen, Count von Waldersee, &c., to the effect that artillery—(1) having taken up an effective position, should stay there as long as its fire has good effect, altering its object and the elevation rather than its position; (2) must never be withdrawn from a position on account of losses, if its fire would still be effective, as long as a man remains to work the

* See Becker's "Erfolge," p. 24 et seq.; Leurs's "Artillerie de Campagne Prussienne," p. 95; Home's "Modern Tactics," pp. 128, 132, 157, &c.; and most pamphlets and lectures of the newest school, at home and abroad.

guns; (3) must never fire on artillery if there is anything else within effective range: and it is convenient to deal with them at this place, as being distinct propositions not particularly dependent on one or the other school.

As to No. 1, when we come to consider how intensified has become the definition, both in time and space, of the absolutely critical portion of the ordinary attack or defence, since the enormous development of the powers of the breech-loading rifle, it will appear somewhat too easy-going to content ourselves with simply a "good effect," but we shall claim, for the arduous circumstances of the other arms, the very utmost that can be wrought by the artillery at the critical spot and the critical moment; nor will the telling up of a long tale of loss inflicted, on the enemy in general, afford compensation for the defeat of a particular operation on which the success of the *whole* may be dependent.

As to No. 2, it will occur to most minds that there may be occasions when, if it be infeasible to reinforce the much-worsted batteries, it will be wiser to withdraw what remains of them and keep it for further uses, than to leave it to be "finished" by the superior force of the enemy, for the sake of roundness of tactical principle.

No. 3 has been generally disposed of already by the later artilleristic writers, who demonstrate that, as at each particular phase of an engagement the action of one particular arm of the enemy acquires the more critical influence, it is on that arm—whichever it may happen to be at the moment—that the artillery must direct its fire, if it would give timely assistance to its allied arms. Prince Kraft has, indeed, supported the original injunction by laying down the position that "the *decision*, either in attack or defence, always lies in the overthrow of the other arms; this once achieved, the enemy's artillery is thereby rendered innocuous." But this appears, on investigation, to be rather a theoretical definition of ultimate purpose than a practical exposition of the methods necessary towards its achievement. No doubt, any one of the three arms, if deprived of the support of the other two, has very little prospect of successfully opposing a force more complete in its component proportions; but the alliance of the three arms should be far too intimate, their mutual assistance far too ready and well-timed, to allow of the enemy attempting to dispose of one arm after another—to deal with independent parts instead of a combined whole; and he who, seeking only to inflict loss on his opponent's infantry, should allow the opposite side to establish a preponderating superiority in artillery, would find himself very awkwardly situated for the next moves of the game.

These maxims should therefore be regarded rather as a manner of cutting the Gordian knot, suitable to the occasion of such as were confident in their own superiority of force, and merely required from this arm a particular definite action; but they are not solutions, useful to those who come afterwards, of the problem, "how to apply the available artillery so that it shall most conduce to the success of the *whole*."

And as to the treatment of the wider questions, introduced above from out of contemporary literature, of the character of modern artil-

lery and its application in war, we shall find, on examination, the same positive Alexandrian method to underlie much of the new German style of settling tactical difficulties. This consciousness of abundant force, and a certain very natural and perhaps admissible spirit of national glorification, have imparted to recent artilleristic doctrine a boldness and an exaltation that must be again eliminated before its prescriptions can be allowed to pass as pure and sound. The Russians have a proverb that "by knocking one's head against each side of the corridor, one attains to walking straight down the middle." Now, the Prussian artillery may well be considered to have touched, in 1866, one of the boundaries of the true path of progress—to wit, excessive reserve; it may be suspected to have gone over, since 1870, far towards the other extreme—viz., overweening confidence. Oscillations between limits have marked the advance of every progress hitherto known to history, whether moral or physical.

Can we, for instance, admit that artillery is to-day "the deciding arm," and that by employing it in this sense the Germans won their recent victories? Very good claims have been made for the cavalry—that their enlightened and extended manner of action, providing complete concealment of the German plans together with full insight into those of the enemy, necessarily secured for their own side the superiority at any point required, and therefore tactical victories and strategic success; and the world is full of books to show the preponderating importance which the German infantry tactics acquired by their scientific and well-studied adaptation to the requirements of the new arms. Nor have the most transcendent recent achievements of artillery secured the desired result without the ready co-operation of infantry. St. Privat, in flames, and smashed into wreck by the concentric fire of more than 200 guns; Floing and Illy at Sedan, their plateaux scoured everywhere with shell from front and flanks; were not won and made useful to victorious purpose without, as usual, concluding infantry assault.

In fact, it appears that during the last war each of the three arms came out in a more important *rôle* than before, and afforded more telling aid to its neighbours; that now, more than ever, each is necessary to the others; each exercises a more distinct and indispensable office in co-operating towards the success of the whole;* and that, as the world goes on, and military science, amongst the others, advances, the difference between an organised army, of justly concerted parts, and an armed crowd, of whatever bulk, becomes more formidable daily.

The claim to independent predominance for the artillery being so far, for the present at least, set at rest, there remains the tactical method which appears to be bound up with it. The long line of guns, pushed up at all speed to within striking distance of the enemy, covered

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* A recent contributor to the "Deutsche Heeves Zeitung" speaks of "the watchful eye, the cavalry; the mighty far-reaching arm, the artillery; the body, supporter of the combat, the infantry."

Sir Garnet Wolseley has, indeed, in his "Soldier's Pocket-Book," laid down the position that "campaigns can be carried on without cavalry or artillery;" but it can hardly be supposed that this was intended to refer to warfare amongst civilised nations.

by "some squadrons," supported by the infantry of the advanced guard, and half-an-hour's march (at a moderate average) in advance of the main body—is this the best disposition for effecting the purpose required, viz. the covering the deployment of the main body, and preparing the way for its action, by shattering the dispositions of the enemy and establishing an artillery superiority from the commencement? I would say decidedly no; for all that it told so successfully against the ill-prepared and overmatched armies of France; because it involves great peril, and does not afford the greatest effect. The peril is that an enterprising enemy, prepared for such tactics, with presumably better acquaintance with the ground, will be liable to make himself, by energetic attack on the small covering forces and on the flanks of the line of guns, suddenly master of the greater part of his assailant's artillery, and thereupon to carry out his succeeding measures with much convenience and success. Even supposing the tactical connection with the main body to be so well provided for as to preclude the possibility of such enterprises by the adversary, he may, at any rate, by engaging a portion of the grand line of guns with careful skirmishers, by menacing its manœuvres with cavalry, and by concentrating the effect of his own smaller and handier batteries on a part —probably a flank—of the line, succeed in wresting to himself that superiority which the precipitation of the whole of its artillery was intended to establish for the other side. And here the examination passes gradually from the question of security into that of effectiveness; from the defensive to the offensive capabilities of the new method. It becomes expedient to reconsider broadly the nature of modern field artillery fire—which appears to have been somewhat overlooked in the recent popular proclamations of the virtue of overwhelming mass. After the establishment of its leading principles, their application to the various circumstances of our theme will be simple and short.

The action of artillery projectiles is typically exhibited under two distinct principal forms:—

In the simplest and most commonly applied, the projectiles arrive perpendicularly to the front of the formation which may be under treatment: in the most scientific and most decisively effective, they travel along that front.

In the former, it may happen that but meagre objects offer themselves in the path of a large proportion of the missiles. Exactness of gunnery (including not only the general service of the piece and the correctness and reliability of its various material appurtenances, but, moreover, the estimation of varying distances, true elevation, and correction of errors—tasks the importance of which practical artillery officers will recognise as hardly to be exaggerated), will be of vital necessity; and the practice is liable to be met, on even terms, by the fire of the whole front assailed.

In the latter, sure plentiful work awaits the whole course of every shot. The gunnery—since the depth of the object accommodates it to the reception of all projectiles, high and low—can hardly be amiss; and the practice, undisturbed by the fire of the front upon which it is employed, may exhibit the most effective achievements of which the

arm is capable, whilst their moral working will be enhanced in proportion to the impossibility of reply.

The force of this comparison becomes abated in one of its particulars under one condition only:* as the range diminishes, so does the greater need of good gunnery to direct fire disappear; but a nature of fire whose admitted inferiority is only then least manifested when the ranges are of the shortest and the gunnery is of the most insignificant, cannot be supposed to exhibit fairly the peculiar advantages of rifled artillery.

In flanking fire, then, dwells the most incontestible ascendency. This has indeed never yet been questioned, only somewhat lost to mind, amongst the successful exhibitions of the new powers of the arm in direct fire, well as these very powers pointed out the more important direction which its development might take.

Of the infinite gradations between, or combinations of, these two kinds of fire, cross fire—partaking, according to its degree, of the nature of flanking fire, and inflicting, by its distracting and disconcerting action, a peculiar moral disorganisation—may be regarded as a very appropriate application of the special functions of the new field guns.

There must further be considered the question, How is the necessary position for such action to be attained? Obviously by manœuvre—opportune, adapted to the movements of the enemy, not *in place* only, but equally *in time*. "What is the use," said May, reviewing the war of 1866, "of an artillery that makes capital practice indeed, but which is never in the right place?" "At the right moment," must be added, if we would reap the advantages due to flanking and cross fire. Flanks are withdrawn, or covered, fronts are changed, the battle moves bodily on, unless the critical moment is seized by the most ready, unless the long line taken "flagrante delicto" in its unwieldy deployment be crushed where it stands by more apt and mobile batteries, and rendered incapable of the farther prosecution of its purpose. Hamley has defined manœuvres to be "the quick, orderly change of highly trained and flexible masses from one kind of formation to another; or their transference from point to point of a battle-field, for purposes which become suddenly feasible in the changing course of the action." And there can be little doubt that very decisive artillery purposes will become suddenly feasible upon the prematurely developed gun-display of the enemy, if we be ready for it, with highly trained and flexible masses.

In order to be thus ready, it will be necessary, not to imitate the prescribed precipitation of all available guns on the front, but, on the contrary, to hold the force of artillery (whatever its proportions, provided it be all destined to forward one and the same operation), prepared to act in at least two parts—one of them, by engaging the enemy without too deeply compromising itself, to force him to deploy and declare his force and dispositions; the other to await, unseen if it may

* Excepting, of course, in the case of deep columns, which may hardly be expected on the battle-field for the future.

be, those dispositions, and to make itself ready, against the time of their completion, suddenly to combine its fire with that of its already engaged comrade in the form most suitable to the situation. Two such corresponding parts, having independence of movement but tactical connection, and attaining, between them, always to some employment of flanking or cross fire, could hardly fail (as far as the artillery engagement is concerned—and such is the staple of the commencement of modern battles) to put the long line, though of vastly superior force, irredeemably in the wrong.

I used the expression "at least two parts" in order not to preclude the possibility of having, in addition to the two larger tactical bodies, a small reserve, to provide for occasional needs—more particularly in defensive operations. I am not unmindful of the fact that the majority of the recent writings forbid the retention of any artillery at all for reserve, and support their injunctions for its ever-more-forward development by instancing how the larger part of the powerful French artillery reserve at Gravelotte never came into action at all, though the right of the position was simply crushed by the superiority of the German artillery concentrated upon it;* but the instance simply shows that a reserve, like all other military means, should be utilised at the proper moment. Nor should the title of "reserve" be any impediment to such use; as was well manifested in the same battle by that portion of the German artillery now entitled "corps," but at that time "reserve," which, however designated, was brought into equal action with that of its divisional precursors. Nor has anything been yet adduced to weaken the authority of that leading, most typical, and signal example of successful artillery disposition given to the world by Senarmont at the battle of Friedland. He divided his available 36 guns into two correlated parts of 15 guns each and a reserve of 6; and, carrying everything at his end of the field absolutely away before him, straightway decided the battle, and achieved a greater success than has been claimed before or since for any artillery force of comparable magnitude.

This scheme of employing the artillery concerned in each operation in two principal parts (their relative proportion to one another varying according to circumstances of ground, forwardness or cautiousness of the enemy, and ultimate object of the operation), may appear to depart too widely from the universally recognised maxim that guns should be massed for decisive effects; but the use of the term "mass" appears to need re-consideration nowadays. In the Napoleonic times, when the word and the practice came in together, it was necessary, in order to bring the fire of a large number of guns to bear on one point, to plant them as near to one another as their principles of formation would allow: in fact, concentration of fire demanded concentration of guns. To-day, nothing of the sort is necessary, and the nearness of the artillery units to one another should be determined on other grounds—such as the facilities of command and control and combination of fire, as also of conferring and comparing experience gained in the course of

* See Home's "Tactics," p. 132.

the practice,* and, of course, the configuration of the ground. The original intention of the word having passed away, it becomes a question whether its use should be continued, although the works of Hamley and Owen have done as much as was possible for it by deciding that the mass may be disposed in separate parts; but in this form it amounts simply to disposition for a definite purpose, and the true import of the name is no longer there. But taking the artillery mass in its widest sense, and recognising all the critical examples collected in Owen's "Modern Artillery," it will appear that its application was only then decisively successful when there was included with it, more or less, the element of decidedly convergent or flanking fire—as at Friedland, Bautzen, Gross Beeren, Warsaw, Gravelotte, Sedan; and that in the instances where the same element was wanting, no proportionate success was achieved—as at Wagram, Inkerman, and Gettysburg.

Therefore, although the effect of concentrated artillery fire has become, since the extreme development of the defensive capabilities of the infantry weapon, more than ever important and indispensable to the carrying out of most of the manœuvres of the battle-field, let us seek to produce it by a just application of mobile individual parts to a combined purpose; by an extension (without injury to the connection of mutual support) of the tactical dispositions; and not by the precipitate presentment of the whole of our artillery in one grand battery —which latter involves great risk, exposes the *hand,* draws no aid from science, as to place or time, and is but moderately fitted to effect its purpose.

The duties of an advanced guard being absolutely determined to the preparation of the action of the main body, include principally two functions—the reconnoitring and the engaging: the former, for finding, feeling, and ascertaining the strength and disposition of the enemy, may be held to include also the screening of the corresponding particulars from the enemy's observation; the latter for *containing* him, and obstructing either his retreat or his attack whilst the main body is completing its dispositions.

The former function is generally executed principally by cavalry; of which, if there be no large detached force well ahead of the whole, there must be a stronger proportion at the head of the advanced guard. In either case this cavalry will need the assistance of horse artillery; not merely for the shelling of the enemy's posts and sheltered ground, but more especially to force him to deploy, to declare himself, and, in the case of large opposing bodies of advanced cavalry, to manœuvre. These purposes are declared by most authorities to be amply provided for in the allotment of one battery per brigade; yet it is very clear that, if the horse artillery be of a sufficiently mobile character not to

* This comparing of notes and observations has been much insisted on as one of the advantages of the grand-line-of-guns system; but the position of the batteries about the middle of such lines for observing or obtaining corrections of their practice must surely be less favorable than that of more distinct and less hampered units.

hinder the manœuvres of its own cavalry, that side, in an extensive and otherwise evenly matched cavalry engagement, which is able to establish an artillery superiority, and to apply a portion of it in the second or flanking *rôle* discussed above, must defeat the successive dispositions of the other, must drive it into retreat—becoming the more headlong in proportion to the amount of its distance in advance of its own army—must destroy the other's screening power whilst preserving its own, and may succeed, by the opportune co-operation of one surplus horse artillery battery, in rending the "strategic veil" of the enemy beyond repair for the campaign.

The special action of the horse artillery attached to the cavalry has generally been distributed under the following heads:—

1. Covering the deployment of the cavalry.
2. Preparing the place for its attack.
3. Preventing the overthrown enemy from rallying.
4. Covering the retreat of its own cavalry, if unsuccessful.

And the principal changes introduced to accommodate the new powers of the arm have been, increased independence of manœuvre and of selection of position—which is to be exercised more rarely but on a much larger scale than formerly. But to the above heads a new one may now be added, viz.:—

5. Attacking the enemy's disposition, by means of artillery fire, under the protection of cavalry.

That is to say that, under circumstances favorable to artillery fire, this latter will be the principal consideration. In the old days the mutual relations between these two arms were held to be analagous to those existing between the musket and bayonet. The relations of these latter, by the intense development of the power of fire, have been radically altered; but, with certain reservations, the parallel holds good in its new form.

When the reconnaissance comes properly within the functions of the advanced guard, the three arms are brought into play, according to the nature of the country, and advantageous posts are occupied by both sides. The intentions of the advanced guard being ever to challenge, but never to fight if it can help it, it pushes everywhere, merely to obtain an answer; and in the earlier stages of the affair this may be obtained more conveniently by the accurate delivery of a few shells from commanding positions, even at ranges of 3000 yds. and upwards, than by more pushing and compromising enterprises. As the general position becomes more evident, the whole artillery of the advanced guard must be in readiness to protect the deployment of its own infantry, to check heavy bodies of the enemy, and to engage his artillery, if seriously hindering the dispositions. The second function, *containing*, is now entered upon; and according as the enemy's purpose shall appear to be to withdraw himself, to remain in occupation of a defensive position, or to attack with all speed, so will the artillery be well employed in threatening his flank, in trying his front, or in taking up secure positions from which to shatter his attack. Such positions

should be attainable somewhat wide of, and retired from, one or both flanks of the infantry, as the outer flank of the guns may always be covered by the successively arriving artillery from the main body of the army. The time of opening fire will be, in the first case, whenever the guns will bear effectively, and it will be continued, if necessary, by their advancement in alternate parts; in the second case, when its own infantry is prepared for a forward demonstration; in the third, when the enemy is fully committed in his attack, and becomes exposed, at the most effective range, to a perhaps unexpected fire. In each of these three cases a certain amount of preliminary fire, to occupy the general attention of the enemy, is taken for granted, and the period specified is for the application of the utmost energy. Many combinations, of course, will occur amongst the three cases, and the scheme of artillery action will be regulated by the commander of the advanced guard, according to his purposes during the course of the engagement, until they become merged in those of the commander of the army.

The artillery of the main body of an attacking force, having always for its principal object to facilitate the occupation by its own infantry of a portion (or thereafter the whole) of the enemy's position, must nowadays be guided in accordance with three peculiar conditions arising out of the increased powers of musketry fire. It has come to be generally recognised that—

First, infantry cannot possibly advance up to hostile equal infantry in position without extraneous assistance. The only effective, convenient, and ever-ready method of affording such assistance is the application of artillery fire, to engage the enemy during the advance of the infantry, and to prepare the spot selected for its attack by levelling defences, and driving out, destroying, and disorganising the defenders.

Second, infantry becomes so far loosened and disordered by the confusing nature of a closely contested musketry engagement, that the support of a steady artillery, established in position, is more than ever necessary for the protection, the encouragement, and, it may be, the rallying of the waving and intermittent lines of the battle.

Third, so destructively decisive is modern fire, and so brief the periods during which it is possible for any troops to remain unbroken when fairly exposed to it, that affairs come to be decided at critical moments; and therefore the assistance of artillery fire, to be effective, must be essentially *timely*. If the action of the artillery be too slow, the decision will have been achieved without its co-operation, and thereby the next critical point demanding its action transferred, possibly, to another part of the field.

And it may be laid down generally, on the subject matter of these three considerations, that in proportion as the power of fire of every kind becomes developed, the more are decisive effects produced at peculiar instants, and the more does it become desirable for all the parts of a force to combine, as much as possible, their action at the decisive point and moment. Improved weapons lead absolutely to improved combinations of the three arms; and the necessity of an intimate acquaintance, of secure tactical connection, and of ready reciprocation of assistance, between them is more urgent than ever.

In the case now under consideration, the infantry attack is to be regarded as the object and practical outcome of the action of the artillery. The latter will take up positions, as soon as the general direction of the attack is decided on, and open fire principally upon the enemy's batteries, with some attention also to his posts, and works, and troops where visible. These positions will be generally as near to that of the enemy as the ground will admit of, consistently with a security from interruption and with the maintenance of a steady and carefully accurate fire; and though the features of the ground, and the dispositions of the enemy, and even the condition of the atmosphere, must very largely affect the choice of range, it is probable that a mean distance of one mile, with a margin either way of 4 or 500 yds., will generally satisfy the conditions of this period. As the artillery of the defence is becoming quenched, the infantry of the attack will enter upon its advance, and its own artillery will begin to devote an ever-increasing attention to the infantry position of the defence. By the time that the skirmishing front of the infantry attack comes under the aimed musketry fire of the defence, as much of the artillery of the attack as the ground will allow must be already in its last and decisive positions, bearing directly on the actual point determined for the delivery of the assault, and on the collateral lines; enfilading where it is possible, regardless of losses, straining every nerve (at such short range that none of its efforts will be wasted) to overwhelm with its fire, to disorganise and quell the defenders—daring everything in the intention of bearing the infantry through the last arduous crisis, and of thus securing the success of the whole.

This third (if we have previously reckoned a first reconnoitring and a second engaging) deciding position must be so near to the lines of the defence that their particulars and occupants may be clearly discriminated. A range of 1000 yds., with a margin either way of 4 or 500, according to ground and attitude of the enemy, will probably represent the average distance.

It will hardly be necessary to notice here that new positions must be entered as rapidly as possible, generally by successive parts of the artillery force which is to be moved; nor that every effort, consistent with the avoidance of diffuseness and of loss of mutual support and combination of action, must be made to attain positions flanking those of the enemy. Such positions may be obtained, primarily, by extension of front and advances on either wing—measures generally much more within the competence of the attack than of the defence; secondarily, by the application, to those dispositions which the enemy may have adapted to the original attack, of a fresh force of artillery hitherto undeclared. A force so kept in hand for its opportunity, will indeed have failed to satisfy those arithmetical tacticians who require that each gun should be inflicting some loss on the enemy, from the commencement uninterruptedly to the end of the engagement; but it will be liable to exercise a decisive effect at the critical place and time.* It

* This view, though little in vogue of late, is in fair accordance with that maxim of Napoleon's expressed in the "Memoire de St. Héléne":—"Celui qui sait faire arriver subitement et à l'insu de l'ennemi sur un de ces points une masse d'artillerie est sûr de l'emporter."

would not avail so fully to detach such a force from the artillery originally engaged; as this latter must continue to hold the enemy to a convenient attitude, and to employ, as far as possible, his whole attention.

The same advantages are attained more completely by a successful flank attack, delivered by a wing composed of all arms; and this will, no doubt, be generally preferred to the arduous enterprise of the present frontal attack; but it is without the scope of this essay.

The artillery of the main body of a defensive force, owning, equally with the artillery of the attack, the duty of self-devotion towards the ultimate establishment of the success of its infantry, under the same condition as to the absolute necessity of opportuneness of action, both as to place and time, must recognise, nevertheless, a vast modification of the mutual relations and requirements between the artillery and infantry. Whereas, with the attack, it was evident that the infantry could not attain its end without extraneous assistance, which had to be sought in artillery fire; so now, with the defence, it is clear that the infantry will achieve success and defeat the purpose of the assailant, in the absence of extraneous interference; and to provide, as far as may be, such absence—that is, to ward off, obstruct, and endeavour to put an end to such interference—the artillery fire of the defence must be had recourse to.

Naturally, the first use of artillery, in the defence as in the attack, will be towards reconnaissance and the compelling of the enemy to declare himself and deploy; and the defendant, by his presumably greater acquaintance with the ground, will probably be enabled to utilise very advanced positions, impeding the preliminary action of the assailant, and gaining valuable time for his own. But eventually such advanced posts will have to be brought in, under the protection of more retired batteries; and the assailant developing a powerful artillery, whose ultimate object will be the crushing of the infantry defence, the problem of counteracting it must be undertaken.

The principle of applying the artillery by successive parts—the leading batteries to engage and tempt the enemy into committing himself to dispositions of which the succeeding batteries are to take immediate and decisive advantage, and so on—may not be neglected in an energetic defence; the more particularly if the position has been selected, as is generally so highly to be recommended, with a view to its capabilities for delivering offensive returns. It is, no doubt, to be supposed that the assailant will generally be able to carry the system of extension and outflanking to a greater length than the defendant; but he will be liable to suffer severely in such manœuvres, owing to the defender's superior knowledge of the ground and of the ranges, whilst the latter, having presumably superior positions, and protected by natural or artificial cover, will experience comparatively little loss or hindrance. Still, the superiority of fire must be expected to be established by the artillery of the attack; whilst that of the defence, having engaged it from the time of its first coming within effective range, and having compelled, at the same distance, the deployment of the infantry

advance and its separation into small and mobile units, will find in the latter but an unsatisfactory target for its practice—distant, moving, now extending, now concentrating behind cover, now winding round undulations, now darting forward, and again lying flat on the earth. It will be better not to rely on effecting anything essential during this period, but to occupy the attention of the enemy and to prepare for the critical moment; to which latter purpose, now that the points aimed at by the attack are becoming more distinctly evident, a considerable force of artillery, hitherto uncommitted in action and retained for disposal according to circumstances, will be brought up into convenient supporting proximity. As the hostile artillery endeavours to take up its final and decisive positions, and the head of the infantry advance, coming fairly under the increasing influence of the musketry fire of the defence, begins to exhibit more break in its order, more check in its pace, and more anxiety for its supports and main body to come up with it, the opportunity of the defence is arrived. From every eminence, from retired flanks,* from batteries which hitherto have neither seen, nor been seen from, the distance, but which have measured the ranges and watched the convenient spots where the batteries of the attack must desire to come into action, or where its infantry will be driven to rally together—from all these points, to supplement the already staggering effect of the musketry defence, a sudden and close artillery fire, rapid, and, on account of the small distance, unerring, steady and well regulated because little opposed by artillery or disturbed by random musketry, delivered from front, from flanks, and crossways, must arrest the assailant in the most difficult crisis of his progress, and, having once stopped him, must scatter his dispositions to the winds. Such disjointed fragments of the attack as may be thrown up by the throes of the struggle to the position of the defenders, can hardly be expected to cause much embarrassment.

Should the superiority of force of the assailant be very pronounced, it will be desirable that the flanks of the defence be strong, by nature or art, and difficult to circumvent. The general disposition of the troops must be deep, with freedom for manœuvre, to be ready to meet those attempts on the flanks which must now become so frequent in warfare, owing to the enhancement of the difficulties of frontal attack; and for this purpose, of meeting the unforeseen assaults of the enemy, wherever and whenever he may try to deliver them, and of quickly reinforcing the threatened points, it will be absolutely necessary to have in hand, available without the subtraction of any strength from the already engaged front, and freely applicable to the purpose of the moment, a strong force of artillery. The partisans of the arithmetical theory of the employment of artillery may object to this force being called "reserve." It would not be difficult to devise other names, but this one seems not unfit, if it be not supposed to prevent the readiest

* Positions somewhat retired from the general line of the infantry defence, but affording something of a flanking fire to the ground in front of the same, whilst protected by it from the musketry fire of the attack—filling something of the place of the flanks in the bastion system—often available, enable a calm and regular fire to be exactly delivered at the most decisively effective ranges,

application of the force to the changing courses of the action. Strong reserves of artillery for the defence acquired discredit in the examples of Gravelotte and Königrätz. The former case has been already considered; in the latter it was remarkable that though the powerful reserve was massed adjacent to the right wing, where the crisis actually occurred, yet it arrived to the spot too late to exercise full influence on that event. This is rather a lesson that reserves should be disposed in units of convenient size and situation to allow of the readiest application; and it must not be forgotten that the same reserve, with the cavalry, absolutely saved the army from destruction after its defeat.

The advantages of mobility, extended dispositions, and ultimate concentration of effect at the critical place and time, have been the more emphasised here that little stress has, as yet, come to be laid on them in recognised works on the defence. Up to the commencement of the rifled period, the prescriptions for the artillery dispositions of the defence were so many and various as to appear rather more devised to relieve the conscience of the instructor than to smooth the path of the instructed. To post the heaviest guns on those points from which the enemy's approach could be commanded to the greatest distance; to reserve one's most important pieces to those positions which were not liable to the earlier attacks of the enemy; to provide absolutely that every portion of the ground in front of the position should be raked by batteries to the right and left, as well as swept by a direct fire; to combine, in the crisis of the struggle, the case of the artillery with the musketry of the infantry; to distribute the guns along the front of a position at the rate of one battery to every two battalions*—these are some of the comprehensive and rather conflicting tasks set, in books, with much apparent lightness of heart. The three last, indeed, are still to be found in works of some note as late as 1873–4; but they can only be regarded now as interesting mementos of the conditions which ruled during the great by-gone smooth-bore period.

The duty of the rear guard consists, principally, in securing to its precedent main body immunity from pursuit, attack, or interruption; and is carried out by the employment of every safe means for the retarding and misleading of the enemy. The most effective and available method is the presentation, to the heads of his columns, of a defensive order of battle established in position; which, on his deployment and completion of dispositions for attack, withdraws itself, whilst yet uncompromised by serious engagement, to repeat the same process at the next suitable position.

Its action—like that of the advanced guard—is devoted to containing the enemy and gaining time for its main body; but under this inversion of conditions—that whereas all the time the advanced guard can employ necessarily brings its reinforcements nearer, all the delay that

* The device of spotting guns along the front, at regular intervals, to "mark" it and its flanks, is fairly comparable to the schoolboy's method of annotating his page of MS. by adding stops to it at intervals suitable to the eye and the personal taste. Each system is about equally effective for developing the inherent force of the whole.

the rear guard can effect must take its supports the farther away from it. Under these circumstances, timeliness of retreat becomes a vital consideration to it; and hostile movements threatening its flanks or line of retreat must receive its instant attention. For such needs its dispositions—as in the case of the main body discussed above—must be deep, with much freedom for manœuvre; and the proportion of artillery in reserve—or, if the phrase be preferred, retained "en disponibilité"—greater than ever. The general occupation of the artillery will consist in demonstration—including reconnoitring, threatening, and challenging; its particular, but rarer, employment in the crushing of any immature effort of the assailant to break or drive the rear guard back. For the former, the longest ranges and the earliest opportunities must be taken advantage of, with wide extension, rapid manœuvre, unexpected conversions of front; and horse artillery, backed by cavalry, will be most suited for the immediate maintenance of this sort of intercourse with the enemy. For the latter, the most decisive ranges and the most critical periods of the enemy's advance must be awaited, and all available gun-power concentrated towards the place and the moment when the attack, checked by the containing influence of musketry fire, yet not itself arrived to a position for effective action, shall find itself exposed to the most rapid and certain artillery practice, carried out under the most convenient conditions. As its advance will have been arrested, and its further stay rendered disastrous, it may be expected to retire shattered towards its up-coming reinforcements. The defender—to whom, under rear-guard conditions, but little freedom of offensive return is usually allowable—will then, under the cover of a fresh disposition of artillery, securely re-enter his orderly retreat.

Concluding Observation.

As the influence exerted on infantry tactics by recent developments of the power of fire has been still in the direction of enhancing the dispersion of units together with the concentration of their action, so is it with all tactics which have fire-action for their end and aim.

It has been sought in this paper to bring out into clearer view that Extension of Dispositions (both in width and depth), Mobility, and Readiness in Concentration of Effect (on that place and time which the relations with the other arms render decisively critical), are the elements in the successful employment of artillery which have acquired the greatest increase of importance by the development of the new weapons and of their sphere of action: and that as, in times past, the stiff strength of Frederick the Great's line formations was broken by the rapidly combined action of the more mobile French divisions; as the solid Macedonian phalanx was overcome by the more nimble and more missile-weaponed Roman legion; as even the irresistible might of Goliath was brought to earth by the rapid manœuvre and critically-timed action of David "with his artillery;" so now, and ever, must mere massive strength fall before a skilled application of means.

The results of field artillery fire against the most recent formations in which troops attack, may be here considered, as it were, in an appendix, or note of explanation, to the foregoing separate discussions.

As the most recent formations for the attack have not yet been brought into a thoroughly recognised form, and still constitute in most countries a subject for further experiment and discussion, an examination, short as the space prescribes, of the conditions which must principally regulate their character, appears to be a desirable preliminary.

Before entering within the range of artillery fire, the heavy columns of the attack must be deployed into some less vulnerable order, between the horns of the following dilemma:—

Line is the formation least obnoxious to artillery fire, but it is almost impossible to conduct for a distance under fire.

Column is, of all formations, the most appropriate and handy for manœuvre, but it is the most easily discomfited by artillery fire.

At present, the intermediate measure of a line of small columns of little depth appears the best of the schemes devised. Probably the forming line, and then merely doubling alternate units (such, perhaps, as the companies of the British service, or even smaller ones) the one behind the other, would satisfy the necessary conditions. Such small columns, retaining their intrinsic fitness for manœuvre and supervision, at full interval, but varying it according to circumstances of fire or fight or ground, picking their way, even extending into line when necessary, re-forming as soon as convenient, never stationary whilst in sight, being very many, and of small front and depth, offer but an uninviting target to artillery.

By the time that the head of the attack is entering the outer region of musketry fire (so-called unaimed fire, extending, perhaps, from 1500 yds. away from, up to within 7 or 800 yds. of the infantry position of the defence), the front or firing line will have been thrown forward in extended order some 300 yds. in advance of its supports; the latter, in any variety of small formations, according to individual circumstances, some 500 yds. in front of the reserves or main body. The latter retains its line of small original columns as long as convenient, and is followed by the second line of the force at 5 or 600 yds. distance in some corresponding formation. Still there is no very satisfactory object for artillery.

As the firing or front line of the attack enters upon the zone of aimed musketry fire—within 7 or 800 yds. of the position—its real difficulties commence. It is supposed to advance by short rushes of alternate or successive fractions, for perhaps 50 yds. at a time, lying flat to the earth between whiles; and during this period some theorists will have the men abstain from firing, as safe to hit nothing, whilst others build a great deal on its effectiveness. The supports are to come up as occasion requires, and feed the front; the main body is gradually to diminish its distance, and being supposed eventually to arrive to its skirmishers, engaged in hot but unadvancing fire-fight with the defence at some 3 or 400 yds. distance, its impetus is to carry

them along with it, and the whole mass—skirmishers, supports, and main body—is to rush with cheers right in upon the defender's position, which the second line, arriving afterwards in good order, is then to secure.

Some writers suppose the advance to get within 200 yds. before the final rush, others not so near; some recommend more noise and patriotic cries, some less; but they all agree in collecting the three lines of the attack near to one another, at a general distance of between 500 and 1000 yds. from the position, and in checking the advance of this crowd, shortly afterwards, until the rear of it shall have reached the front. It is to this crowd, or swarm, or succession of swarms, that the application of the artillery fire of the defence will be exactly appropriate; no nicety is requisite, no error possible (if the ground be open), no missile but what must meet its man. Under these conditions, unless the guns can be opposed by some other fire, the effect must, whether acting directly and simply to the front of the attack, or still more if it include some enfilading of its lines, according to the latest* experience and experiment (in war and on the practice ground), be annihilating.

There is, however, one form of attack upon artillery which, well as the arm has recently maintained its reputation for being sufficient to the defence of its own front, it would find it very difficult to counteract independently: viz., the skilful and persistent application of skirmishers—whether in the stealthy approach of scattered, barely seen, surely hitting, infantry sharpshooters, or in the rapid onslaught of galloping cavaliers coming in from all directions. But artillery ought never to find itself thus in independent action; its whole purpose is to help the needs of the other arms, from which, in turn, it will derive its security. If it disregard the purpose of its creation, it must, like all the creatures of the universe, suffer accordingly.

DRESDEN,
March, 1876.

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* By the actual records heretofore extant; but already a fresh advance is being realised by the artilleries of Europe, and the signs are that the movement is not yet drawing to a close.

To replace foot note on p. 450 :—

* By the actual records heretofore extant; but already a fresh advance in ballistic power is being realised by the artilleries of Europe, and the signs are that the movement is not yet drawing to a close.

APPENDIX.

A.

GENERAL ABSTRACT

OF THE

INCOME AND EXPENDITURE OF THE ROYAL ARTILLERY INSTITUTION,

From 1st April, 1875, to 31st March, 1876.

EXPENDITURE.

		£ s. d.	£ s. d.
Printing	Wages	124 1 10	460 4 9½
	Paper and Materials	273 2 6½	
	Type and General Plant	7 2 7	
	Woodcuts	13 16 0	
	Lithography	42 1 10	
Photography			39 5 10
Classes			222 11 0
Taxidermy			1 15 0
Library, and Books for Sale			285 9 4
Museum			38 10 0
Instruments			30 0 0
Carpenter	Wages	18 6 4	107 14 4
	Materials	89 8 0	
Furniture and Repairs			33 5 4½
Subscriptions to Societies			4 4 0
Stationery			233 17 0½
Incidental			57 9 7
Postage and Parcels			79 19 0½
Wages to Clerks and Orderlies			140 2 8
W.O. Photographs and Lithographs			24 1 4½
Building new Printing Office			100 0 0
Fire Insurance	R.A. Institution in £5000	12 10 0	13 18 6
	R.A. Observatory in £1000	1 8 6	
Cash in hand, 31st March, 1876,	of Secretary	11 0 1	512 3 11
	of Messrs. Cox & Co.	501 3 10	
			£2384 11 9½

INCOME.

		£ s. d.	£ s. d.
Cash in hand, 31st March, 1875			271 13 2
Printing			131 0 5
R.A. Institution Prize Essay			10 10 0
Photography			51 8 9
Classes			48 0 8
Taxidermy			1 15 0
Books sold			206 12 1
Carpentry and Picture Framing			71 10 2
Subscriptions	Entrance	63 0 0	1259 19 6
	1870-1	0 10 0	
	1871-2	1 0 0	
	1872-3	8 15 0	
	1873-4	17 7 0	
	1874-5	25 17 0	
	1875-6	1132 12 0	
	1876-7	10 18 6	
Stationery sold			194 18 10
Postage and Parcels			54 1 8½
W.O. Photographs and Lithographs			23 11 6
Dividends on £2000 Consols			59 10 0
			£2384 11 9½

B.

DEBTOR AND CREDITOR ACCOUNT FOR THE YEAR ENDING 31st MARCH, 1876.

DR.

	£ s. d.
Printing, Paper, and Materials	41 13 10
Photography	16 1 11
Classes	2 2 0
Books and Periodicals	32 1 8
Wood, &c., for Carpenter, and Picture Framing	10 10 9
Parcels	2 13 2
W.O. Photographs and Lithographs	1 11 1
Furniture and Repairs	20 16 10
Balance of Account for new Printing Office	257 9 2
General Credit, 31st March, 1876	2598 11 4
	£2983 11 9

CR.

		£ s. d.	£ s. d.
Cash in hand, 31st March, 1876			512 3 11
£2000 Consols Stock, at 93½			1870 0 0
Value of Stock.	Books for Sale	15 0 0	132 11 9
	Stationery for Sale	25 0 0	
	Printing Paper	32 5 6	
	"Handbooks" (unbound)	24 1 3	
	"Kane's Lists" do.	16 5 0	
	Chemicals in Laboratory	20 0 0	
Owing by Members.	Printing	43 2 2	468 16 1
	Photography	7 17 10	
	Classes	19 16 3	
	Taxidermy	1 10 6	
	Books and Binding	60 17 10	
	Carpentry	23 1 2	
	Subscriptions	125 16 6	
	Stationery	139 14 6	
	Postage and Parcels	41 17 3	
	W.O. Photographs and Lithographs	5 2 1	
			£2983 11 9

Examined and found correct,

W. D. AITKEN, Col. R.A., President Sub-Committee.

WOOLWICH, May 10th, 1876.

	£	s.	d.
..	271	13	2
...	131	0	5
...	10	10	0
...	51	8	9
...	48	0	8
...	1	15	0
..	206	12	1
..	71	10	2
	1259	19	6
..	194	18	10
.	54	1	8½
..	23	11	6
.	59	10	0
	£2384	11	9½

ANNUAL REPORT

AND

ABSTRACT OF PROCEEDINGS OF A GENERAL MEETING OF THE ROYAL ARTILLERY INSTITUTION, HELD ON MAY 29, 1876.

MAJOR-GENERAL W. J. SMYTHE, R.A., F.R.S., IN THE CHAIR.

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1. The Committee of the R.A. Institution beg to submit their Annual Report to the general meeting of members.

2. It will be seen from the table (Appendix "C") that there are now 1498 members of the R.A. Institution. During the past year 63 officers have joined the Institution against 50 casualties from death and withdrawal. Amongst the deaths the Committee have particular regret in recording those of Colonel Middleton, C.B., D.-A.-Gen. R.A., a Vice-President of the Institution, Lieut.-Col. C. Young, and Capt. C. C. Saxton, the gold medallist of last year.

3. The financial state of the R.A. Institution is very good, showing a general credit of £2598 11s. 4d. A detailed account of the expenditure and receipts of the year, and a Dr. and Cr. statement are attached. (Appendix "A" and "B.")

4. The new Printing Office authorised last year has been built, and is now in occupation. Its cost (£357) has been virtually defrayed out of the year's income.

5. The subject for the Prize Essay this year was—

"On the Considerations affecting the Positions to be taken up, and the time of opening Fire by Artillery in the Field, under the following circumstances—viz.:

1. As Artillery of the Advanced Guard.
2. " Main Body of an Attacking Force.
3. " Main Body of a Defensive Force.
4. " Rear Guard.

And on the Results of Field Artillery Fire against the most recent formations in which troops attack."

Maj.-General Phillpotts, Maj.-General Sir J. Adye, K.C.B., and Capt. Clayton have been good enough to accept the duty of deciding upon the respective merits of the five essays which have been submitted for competition. Their decision will be communicated at the general

meeting.* The Committee hope that the gold medal will then be ready for presentation.

6. The French and German Classes held at the Institution have been well attended. There have also been Classes in Russian, Hindustani, Drawing, and Mathematics.

A German Class has also been formed amongst the members of the R.A. Institution in Dublin, the Institution bearing two-thirds of the expense, in accordance with Rule XIX., passed at the last annual meeting.

The Committee took upon themselves to authorise the retention of the Russian Instructor's services through the winter, even in the case of the number in the Class falling below the minimum fixed by the Rules. The Committee took this step to prevent officers wishing to study this important and difficult language being deterred by the fear of being left in the lurch after a few lessons, by the breaking up of the Class.

The Class consists at present of only two officers. The Committee leave it to the general meeting to decide whether it shall be continued.

7. Captain Clayton, R.A., has presided at weekly meetings for the study of tactical problems, which have been held during the winter in the Institution.

The Committee consider that the best thanks of the members are due to Captain Clayton for his very valuable instruction on this subject.

8. Last year Lt.-Col. G. G. Pearse was specially thanked for his services in arranging the collection of coins. This year the obligations of the members to this officer have been increased by a very valuable present of Bactrian coins.

The present was accompanied by a letter, in which Lt.-Col. Pearse expressed the hope that officers serving in the Punjab might be induced to follow suit, and that in time an interesting Greco-Bactrian cabinet might be formed—a hope which the Committee cordially endorse.

9. Very valuable presents to the Natural History Museum have been made during the year by Colonel Cadell, R.A., Major Cameron, R.A., H.M. Commissioner for North American Boundaries, and by Mr. Whitely, the son of our Curator. (*Vide* list of presentations in the Appendix "E.")

10. The Committee beg also to call the attention of the meeting to the handsome edition of Mr. Ruskin's works presented to the Institution by the author. The presentation was accompanied by a letter in which Mr. Ruskin stated that he had directed his publishers to forward to the R.A. Institution copies of any future works he might issue.

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* The report of the referees was read to the meeting, stating that they were unanimous in pronouncing the essay bearing the motto "Vis consilî expers mole ruit suâ" the best of those submitted. On opening the sealed envelope, Colonel H. A. Smyth was found to be the author of this essay.

There have been many other additions to the library, both by presentation and purchase. (*Vide* list "D" in the Appendix.)

11. The Committee recommend that the grateful thanks of the members of the R.A.I. be presented to W. De La Rue, Esq., F.R.S., &c., &c., for the valuable advice and assistance generously afforded by him towards the construction of the new telescope, and for the labor he bestowed, at much personal inconvenience, in inspecting and testing the telescope after its erection.

12. The Committee took upon themselves to sanction, subject to the approval of the general meeting, the admission to membership of the Institution of medical officers doing duty with the R.A., but not strictly belonging to the corps. They also sanctioned the re-admittance, without payment of arrears, of medical officers who had ceased to be members on being appointed to other corps.

The Committee were induced to take this step on account of the altered position of the medical officers.

The following changes in the Committee have taken place during the year:—

Major F. Lyon	.....replaced	Major	E. Maitland.
" M. Le F. Taylor	"	"	J. F. Betty.
" J. Ritchie	"	"	W. Stirling.
" M. Elliot	"	"	M. Le F. Taylor.
" F. Duncan	"	"	R. Sandham.
" T. S. Seccombe	"	"	S. C. Kyle.

The Annual Report of the Committee was read to the meeting.

The following resolutions were proposed:—

1. *Proposed by Lt.-Col. Arbuthnot, seconded by Major Stoney, and carried:—*

"That the Report be adopted."

2. *Proposed by Colonel Gordon, seconded by Colonel Aitken, and carried:—*

"That the continuance of the Russian class be left to the discretion of the Committee."

3. *Proposed by Maj.-Gen. Smythe, seconded by Colonel Gordon, and carried:—*

"That a vote of thanks be presented to Warren De La Rue, Esq., F.R.S., &c., &c., for his valuable services in connection with the erecting and testing of the new telescope at the R.A. Observatory."

4. *Proposed by Colonel Gordon, seconded by Colonel Gosling, and carried:—*

"That medical officers doing duty with the Royal Artillery, at the Royal Military Academy, or in the Royal Arsenal, be admitted to membership of the Institution without payment of entrance subscriptions."

The question of the want of accommodation in the present building of the Institution having been brought forward, after a discussion it was—

5. *Proposed by Maj.-Gen. Smythe, seconded by Captain Clayton, and carried:—*

"That the accommodation afforded by the present buildings of the Institution having been alleged to be insufficient, a Committee be appointed to take the question into consideration with the view of suggesting the best method of remedying the inconvenience."

The undermentioned were elected by the meeting to serve on this Committee, viz.:—

President.—Maj.-Gen. W. J. Smythe.

Members.

Colonel W. D. Aitken.	Lt.-Col. H. T. Arbuthnot.
Major F. S. Stoney.	Major W. G. Brancker.
Captain E. Clayton.	The Secretary.

6. *Proposed by Colonel Gosling, seconded by Colonel Gordon, and carried:—*

"That the thanks of the meeting be voted the chairman."

C.

Statement showing Increase and Decrease of Members of the R.A. Institution during the year ending 31st March, 1876.

Rank.	31st March, 1875.	Increase.			Total increase.	Decrease.				Total decrease.	31st March, 1876.
		Promotion.	Retirement.	New members.		Promotion.	Retirement.	Withdrawal.	Death.		
EFFECTIVE LIST.											
General and Regimental Field Officers	465	24	—	4	28	—	8	6	7	21	472
Captains	302	55	—	3	58	24	—	5	4	33	327
Lieutenants	497	—	—	51	51	55	2	9	2	68	480
Paymasters	8	—	—	—	0	—	—	—	—	0	8
Quarter-Masters	5	—	—	—	0	—	—	—	—	0	5
Riding-Masters	5	—	—	—	0	—	—	—	—	0	5
Surgeons-Major	4	—	—	—	0	—	—	1	—	1	3
Veterinary Surgeons	3	—	—	1	1	—	—	—	—	0	4
RETIRED LIST.											
General and Regimental Field Officers	86	—	8	—	8	—	—	2	4	6	88
Captains	42	—	—	—	0	—	—	4	1	5	37
Lieutenants	12	—	2	—	2	—	—	1	1	2	12
Quarter-Master	1	—	—	—	0	—	—	—	—	0	1
Surgeons-Major	5	—	—	—	0	—	—	—	—	0	5
Surgeons	3	—	—	—	0	—	—	—	—	0	3
Chaplain	1	—	—	—	0	—	—	—	—	0	1
HONORARY MEMBERS	46	—	—	4	4	—	—	3	—	3	47
Total	1485	79	10	63	152	79	10	31	19	139	1498

D.

Presentations to the Library, &c.

Essay on the Formation of an Intelligence Department for India. By J. A. S. Colquhoun, Captain R.A.	The Author.
Reports of the Prussian Artillery Committee. 3 parts	The Commandant, School of Artillery and Engineers, Berlin.
Report on the State of the Militia of the Kingdom of Canada, for the year 1874	Lieut.-Col. T. B. Strange.
The Erosion of the Bore in Heavy Guns, and the Means for its Prevention	Anonymous.

Annual Reports on Musketry Instruction at Hythe, from 1855–74 (the year 1857 excepted)	The Commandant, School of Musketry, Hythe.
Painting in Water Colours. Penley	Captain W. H. M. Duthie, R.A.
Examination Papers, R.M. Academy, February and July, 1875	The Governor R.M. Academy.
9 Royal Carriage Department Lithographs	The Secretary of State for War.
6 Royal Laboratory "	
5 Royal Gun Factory "	
34 W.O. Photographs	
Extracts from the Proceedings of the Department of the Director of Artillery. Nos. 3 and 4, Vol. XII.; Nos. 1 and 2, Vol. XIII.	
The Armed Strength of Denmark	
Manual of Field Artillery Exercises, 1875	
Steppe Campaigns. Translated from the Russian by Captain F. C. H. Clarke, R.A.	
Report of the Special Committee on Bronze	
The Franco-German War, 1870–1. Part I., 6th, 7th, and 8th sections. Translated by Captain F. C. H. Clarke, R.A.	
Austrian Manœuvres, 1873	
Map of South Western Arabia	
Conventional Signs used in Military Mapping. 2 copies	
Military Sketch of the Transkeian Territory	
Committee on Explosive Substances. Report on the Experimental Rifled Gun of 38 tons	
Report of the Special Committee on Rifled Guns and High Angle Fire, on the Artillery Experiments at Okehampton, in August and September, 1875	
The New Law Regulating Military Service in Russia	
The Journal of the Royal United Service Institution. No. 79, Vol. XVIII., and Appendix; Nos. 80, 81, 82, 83, Vol. XIX.	The Council of the Society.
Journal of the Royal Geographical Society. Vol. XLIV. 1874	The Council of the Society.
Proceedings of the Royal Geographical Society. Nos. 4, 5, 6, and 7, Vol. XIX.; No. 1, Vol. XX.	The Council of the Society.
Monthly Notices of the Royal Astronomical Society. No. 6	The Council of the Society.
Proceedings of the Institution of Mechanical Engineers, October 1874, January, April, June, July, and November 1875, and January 1876	The Council of the Institution.
Proceedings of the United Service Institution of India. No. 19	The Council of the Institution.
Proceedings of the Scientific Meetings of the Zoological Society of London. Part IV., 1874; and Parts I., II., and III., 1875	The Council of the Society.
Catalogue of Vertebrated Animals	
Minutes of Proceedings of the Institution of Civil Engineers. Vol. XL., XLI., and XLII.	The Council of the Institution.

The Best Practical Method of Promoting Efficiency in the Army, and for Obtaining an Effective and Reliable Reserve, having regard to the existing feeling of the country on the subject. By Maj.-Gen. Sir E. C. Warde, K.C.B.	The Author.
Nuragghi Sardi, and other Non-Historic Stone Structures of the Mediterranean Basin. By Captain S. P. Oliver, R.A.	The Author.
United States Geological and Geographical Survey of Colorado, 1873. By F. V. Hayden, U.S. Geologist	The Author.
A Book of Plates illustrating the Operations of the Army commanded by Prince Ferdinand of Brunswick during the Seven Years' War.....	Lieut.-Col. W. H. Goodenough, R.A.
Manuscript Work in French on Military Engineering, with Book of Plates to illustrate the same	
Operations à faire pour le projét d'une place. MS.	
Théorie du service militaire suive de quelques principes de Tactique, et de Castramentation pour les elêves de l'ecôle du Génie. MS. ...	
Manuscript work in German on Fortifications, with Book of Plates	
Do., do., on Mines and Countermines	
Course of Instruction in the School of Military Engineers. German MS.	
The Russian Artillery Journal for 1875. 10 parts	The Russian Government.
The Recueil Militaire. Nos. 1, 2, and 3, 1875	
Professional Papers of the Corps of Royal Engineers. Vol. XXII., 10 copies	The Editor.
On Temperature attainable by Rock Crushing and its Consequences. By R. Mallet	The Author.
Volcanic Energy; an attempt to develop its True Origin and Cosmical Relations. By R. Mallet, F.R.S.	
Pamphlet on the Origin and Mechanism of Production of the Prismatic (or Columnar) Structure of Basalt. By Robt. Mallet, F.R.S. ...	
Smithsonian Report, 1873	The Council of the Smithsonian Institution.
Washington Astronomical and Meteorological Observations, 1872	
Report of the United States Geological Survey of the Territories. By F. V. Hayden	The Author.
List of Elevations principally in that portion of the United States West of the Mississippi River	The Author.
Catalogue of the Publications of the United States Geological Survey of the Territories ...	The Author.
Memoir of the Life of Admiral Sir Edward Codrington. By Lady Bourchier. 2 vols....	The Authoress.
Researches on Explosives. Fired Gunpowder. By Captain Noble, late R.A., and F. A. Abel, F.R.S.	The Authors.

Unarmoured Ships. By T. Brassy, M.P.	The Author.
Photograph of the Harbour of St. John's, Newfoundland, during a severe frost, 11th March, 1875	Major H. J. F. Shea, R.A.
On Fog Signals, &c. By Vice-Admiral R. Collinson, C.B., Major Maitland, R.A., and Staff Commander J. R. Richards	Major Maitland, R.A.
Hart's Quarterly Army List	R.A. Library, Woolwich.
Abstract of the Results of a Study of the Genera Geomys and Thomomys; with Addenda on the Osteology of Geomyidœ, and on the Habits of Geomys Tuza. By Dr. Elliott Cones, U.S. Army	The Secretary of the Interior United States.
Contributions to Terrestrial Magnetism. No. 14. By General Sir E. Sabine, K.C.B., R.A.	The Author.
Plates of Netherlands Artillery *Matériel.* 37, 38, 95, and 99	The Netherlands War Minister.
Memoranda, &c., on the Malayan Peninsula and Perak, drawn up in the Military Department of the Government of India, 1875	Lieut. E. H. H. Collen, late R.A.
The Artillerist's Handbook of Reference. By Lieuts. G. Will and J. C. Dalton, R.A.	The Authors.
The Defence of a Position Selected as a Field of Battle. Royal Engineer Prize Essay, 1875. By Captain T. Fraser, R.E.	The Author.
Use of the Suspension Principle for Military Bridging. By Lieut. T. Fraser, R.E.	
Greenwich Magnetical and Meteorological Observations, 1873	The Astronomer Royal.
Military Industrial Training Schools. By W. J. Hamilton	The Author.
Proposed Plan for giving increased Efficiency and greater Mobility to a M.L.R. 9-pr. Field Battery. By Major W. B. E. Ellis, R.A. ...	The Author.
Warlike Woolwich: A History and Guide. By W. T. Vincent	The Author.
Lectures Delivered at the School of Military Engineering, Chatham. Iron Fortifications. By Colonel T. Inglis, R.E.	The Commandant, School of Military Engineering, Chatham.
Studies on the Tactics of Infantry. II. By Brig.-Gen. M. A. S. Biddulph, C.B., R.A. ..	The Author.
Report on the State of the Militia of the Dominion of Canada, 1875	Lieut.-Col. C. T. Irwin.
Revised Army Regulations. Vol. II.	
Regulations for the Commissariat and Ordnance Store Departments	The D.-A.-General, R.A.
Regulations for the Army Hospital Corps	
An Essay on Potential Energy and the Conservation of Energy. By Captain J. B. Parkin, retd. R.A.	The Author.
Camden Society Publications, 1875	
The Autobiography of Anne, Lady Holkett	Major F. S. Stoney, R.A.
Letters of Humphrey Prideaux to John Ellis ...	
The Camden Miscellany. Vol. VII.	

Works presented by Mr. Ruskin.

SESAME AND LILIES:—1. Of Kings' Treasuries. 2. Of Queens' Gardens. 3. Of the Mystery of Life.

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Polyphasia nigra.
Hierococcyx varius.
Coccystes melanoleucos.
Eudynamys orientalis. ♂
Ortygornis ponticerianus.
Perdicula asiatica.
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Caprimulgus sinensis.
Sitta castanoventris.
Dicrurus longicaudatus. ♂ ♀
Edolius paradiseus. ♂ ♀
Chibia hottentota. ♂ ♀
Graucalus macei. ♂ ♀
Lanius cristatus.
" hardwickii. ♂ ♂
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Corvus splendens. ♀
Temenuchus malabaricus. ♂ ♀
Ploceus baya. ♂ ♀
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" indicus. ♂ ♀
Carpodacus erythimus. ♂
Euspiza luteola. ♂ ♀
Melophus melanicterus. ♂
Alauda gulgula. ♂ ♀
Calandrella brachydactyla. ♀
Mirafra erythroptera. ♀
Pyrrhulauda grisea. ♂
Gecinus striolatus. ♂
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Dacnis melanotis. ♂
Tyrannus melancholicus.
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Sturnella bellicosa. ♂
Tanagra cœlestis. ♂
Tachyphonus melaleucus. ♂ ♀
Phrygilus fruticeti. ♂

Birds presented by the British North American Boundary Commission.

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Cerchneis sparveria.
Accipiter fuscus.
Circus hudsonicus. ♂, juv.
Asio americanus. ♂ ♀
Picus villosus. ♀
Coccyzus erythrophthalmus.
Charadrius virginicus.
Tringoides macularius.

Birds from New Granada, presented by H. Whitely, Senior.

Cephalopterus ornatus. ♂ ♀

List of Papers published in the "Proceedings" during the past year.

Explanatory Notes on Bashforth's "Motion of Projectiles." By Captain E. Kensington, R.A., Instructor in Mathematics R.M. Academy (*continued*).

Bronze Steel. By Captain J. F. Owen, R.A.

On Centralisation, as applied to the Manufacture of War Matériel. By Captain C. C. Saxton, R.A. The R.A. Institution Prize Essay of 1875.

Annual Report and Abstract of Proceedings of a General Meeting of the Royal Artillery Institution, held on May 20, 1875. Colonel W. C. F. Gosling, R.H.A., in the chair.

A List of some Remarkable and Important Explosions of Gunpowder which are recorded as having occurred previous to 1866. Compiled by Major V. D. Majendie, R.A., H.M.'s Inspector of Gunpowder Works.

Notes on Gunnery Instruction. By Lieut. G. Mackinlay, R.A.

On Accidental Explosions. A Lecture delivered at the Royal Institution of Great Britain, in March, 1875, by F. A. Abel, F.R.S., President of the Chemical Society, Vice-President of the Society of Arts and the Society of Telegraph Engineers, Hon. Member of the Royal Artillery and Royal United Service Institutions, &c.

English *versus* German Field Guns; a Comparison. By Lieut. S. C. Pratt, R.A.

Time Fuze, proposed by Lieut. W. Martin, R.A.

Our Service Small-Arms; their Manufacture and Repair. By Major F. S. Stoney, R.A.

The Application of Professor Bashforth's General Tables to Problems in Practical Gunnery. By Captain J. Sladen, R.A., Professor of Artillery, R.M. Academy.

Table of the Dimensions, Weight, and Tonnage of Carriages, &c., in use with an Army Corps. Communicated by Colonel G. T. Field, R.A., Superintendent Royal Carriage Department.

New Garrison Carriages. By Major W. Kemmis, R.A.

The 80-ton Gun. By Major E. Maitland, R.A., Assistant Superintendent Royal Gun Factories.

Instruments employed by the Committee on Explosives for Investigating the Action of Gunpowder in the Bores of Guns. By Captain C. Jones, R.A., Assistant in the Experimental Branch of the Director of Artillery's Department.

Recent Historical Notes connected with the Royal Regiment of Artillery. (No. I.) Brig.-General E. T. Michell. (Communicated by Major F. Duncan, R.A.)

"Translation" published during the year.

Trial of the 8·7 c.m. Experimental Half-Battery, at the Steinfeld. (Compiled from official documents.) Translated from the "Mittheilungen über Gegenstände des Artillerie-und Genie-Wesens," for October, 1874, by Major J. R. Oliver, R.A.

"Short Note" published during the year.

Mounting two 11-in. Muzzle-Loading Rifled Guns on Westmorland Fort, Spike Island. By Lieut.-Colonel W. Denis-de-Vitre, R.A.

Afternoon Lecture delivered at the R.A. Institution during the year.

Captain C. Jones, R.A. ..... "Instruments used by the Committee on Explosives, for ascertaining the Velocity and Pressure, with the 80-ton and other Heavy Guns."

Evening Lecture delivered at the R.A. Institution during the year.

John Rae, Esq., LL.D. ..... "Arctic Experiences."

THE 80-TON GUN.

BY

MAJOR E. MAITLAND, R.A.,

ASSISTANT SUPERINTENDENT ROYAL GUN FACTORIES.

THE early history of this remarkable weapon formed the subject of a paper contributed by the present writer to these "Proceedings" last January. The causes which led to the designing of the gun; the object sought to be obtained by it; the progress of its manufacture; its proof; and the first series of experimental rounds fired from it by the Committee on Explosives, were therein described. It was shown that the results obtained somewhat exceeded anticipation; and while it had been hoped that the penetrating power would reach the point sought for in the final stage, there was now a possibility that the gun would do the work assigned to it, even in the sub-calibre of 14·5 ins., to which it was at first bored.

It was stated that the highest admissible result then obtained was yielded by a charge of 230 lb. of powder in cubes of 1·7-in. edge, which propelled a shot weighing 1260 lb. with a velocity of 1543 f.s. The useful work, or "energy," produced by the explosion reached 20,780 ft. tons, while the mean pressure in the powder-chamber did not exceed the limit laid down by the Committee; though it should be remarked that an undesirable pressure was recorded at A. From this result, then, it appeared at least possible that the gun, even in its 14·5-in. calibre, would perform its task—viz., the piercing of 20 ins. of iron armour, strongly backed, at a range of 1000 yds.; and it was expected that the further development of its powers would place the question beyond doubt.

The bore sustained the trials without any perceptible injury or change; and the paper alluded to carried the history up to the point where the gun was placed in the boring machine, that its calibre might be enlarged to 15 ins.—the intention at the time being to proceed by half-inch stages to a final diameter of 16 ins.

I have now to give an account of the progress of the experiments since made. On the completion of the boring up of the gun to 15 ins., it was again mounted on its travelling firing carriage and taken to the Proof Butt. Shot of the weights previously fired were provided, and a sufficient quantity of each size of powder used in the former trials was preserved, so that the results should be directly comparable.

The annexed table (A) gives the particulars of the rounds fired.

TABLE A.

Experiments with 80-*ton R.M.L. Gun. Expl. No.* $\frac{405}{2}$. *Calibre* 15·0 *ins. Comparative rounds in* 14·5-*in. calibre in italics.*

Round.	Description of powder.	Charge. Weight.	Charge. Length after loading.	Charge. Cubical ins. per lb.	Projectile. Total weight.	Velocity. At muzzle.	Velocity. At 1000 yds.	Maximum pressure.	Mean pressure on powder chamber, A, 1, 2, and 3 gauges.	Energy. Total. Theoretic.	Energy. Total. Realised.	Energy. Per pound of powder.	Energy. Per ton of mean pressure on pdr. chamb.	Factor of effect.	Energy. Total. At the muzzle.	Energy. Total. At 1000yds.	Energy. Per inch of shot's circumference. At the muzzle.	Energy. Per inch of shot's circumference. At 1000yds.
		lb.	ins.	c. ins.	lb.	f.s.	f.s.	ft. tons per square inch.	ft. tons per sq. in.	ft. tons.	ft. tons.	ft. tns.	ft. tons.	per cent.	ft. tons.	ft. tons.	ft. tons.	ft. tons.
1	Cubical ..... / 30. 9. 75 / 2. 12. 75 / 1·7-in. edge ..... mixed...	220	33·5	25·6	1265	1514	1401	22·3 at A and 1	22·0	22,220	20,101	91·4	913·7	90·4	20,101	17,212	427	365
13		*"*	—	—	*1259*	*1502*	*1396*	*25·1 at A*	*22·9*	*21,762*	*19,637*	*89·3*	*857·5*	*90·2*	*19,637*	*17,009*	*431*	*373*
2	" "	230	34·5	25·3	1266	1546	1430	25·5 at A	22·5	23,005	20,975	91·2	932·2	91·1	20,975	17,946	445	381
15	" "	*"*	—	—	*1259*	*1543*	*1435*	*26·6 at A*	*24·9*	*22,138*	*20,780*	*90·3*	*834·5*	*93·9*	*20,780*	*17,972*	*456*	*395*
3	" "	230	34·5	25·3	1466	1469	1374	27·6 at A	26·2	23,005	21,930	95·3	837·0	95·3	21,930	19,186	465	407
—	*No round corresponding to 3 was fired in 14·5-in. calibre.*																	
4	2·0-in. edge.	250	36·5	24·7	1266	1536	1421	24·9 at A	23·2	24,293	20,705	82·8	892·4	85·2	20,705	17,720	439	376
21	"	*"*	—	—	*1259*	*1523*	*1416*	*26·6 at A*	*24·8*	*23,656*	*20,244*	*81·0*	*816·3*	*85·6*	*20,244*	*17,499*	*444*	*384*
5	"	220	33·5	25·6	1466	1373	1286	22·5 at 2 and 3	22·4	22,220	19,158	87·1	855·2	86·2	19,158	16,806	407	357
20	"	*"*	—	—	*1465*	*1366*	*1286*	*27·3 at A*	*24·4*	*21,762*	*18,950*	*86·0*	*776·6*	*87·1*	*18,950*	*16,795*	*416*	*369*
6	1·7-in. edge.	220	33·5	25·6	1466	1423	1332	24·8 at A	23·8	22,220	20,577	93·5	864·6	92·6	20,577	18,030	437	383
19	"	*"*	—	—	*1465*	*1414*	*1330*	*26·9 at A*	*25·1*	*21,762*	*20,305*	*92·3*	*809·0*	*93·3*	*20,305*	*17,964*	*446*	*397*
7	2·0-in. edge.	230	34·75	25·3	1466	1397	1308	22·4 at A	21·9	23,005	19,833	86·2	905·6	86·2	19,833	17,386	421	369
—	*No round corresponding to 7 was fired in 14·5-in. calibre.*																	
9	1·5-in. edge.	220	33·5	25·6	1265	1546	1430	24·5 at A	23·3	22,220	20,975	95·3	900·0	94·4	20,975	17,946	445	381
12	"	*"*	—	—	*1266*	*1535*	*1428*	*26·3 at A*	*24·1*	*21,762*	*20,564*	*93·5*	*853·3*	*94·5*	*20,564*	*17,797*	*451*	*394*

The results obtained in the 14½-in. calibre are shown in italics, underneath the similar ones obtained in the 15-in. calibre. We have here six pairs of rounds which are comparable in all respects; and it will be seen that the increase of calibre has so facilitated the combustion of the charge and added to its effect upon the projectile, that a higher velocity accompanied by a lower pressure has in every case been gained. These advantages are due to the shortening of the cartridge, which thus burns up more uniformly, and to the enlargement of the base of the shot, so that a greater surface is exposed to the action of the gas. On the other hand, the enlargement of the diameter of the shot causes it to be more retarded during flight by the air, and also enables the armour-plate to present greater resistance to penetration. Owing to these two causes, then, we see from the last column of Table A that when equal charges are employed a positive loss in penetration at 1000 yds. results from boring up the gun. This, however, is not the right way to calculate the powers of the respective calibres. The object of the artillerist is to get the best ratio of penetration to pressure, not to charge; and if an increase of calibre enables him to use larger charges without increased pressures, and so to obtain additional penetration, his object will have been gained. Thus, if round 2 in the table be compared with round *13*, it will be seen that 230 lb. of 1·5-in. cubes can be fired in the 15-in. bore without giving quite so much mean pressure as is given by 220 lb. of the same powder in the 14½-in. bore, while a higher penetrating power is obtained. Again, comparing rounds 7 and *20* in the table, fired with the 2-in. cubes, it appears that with exactly the same penetrating power, at 1000 yds., a considerable reduction in pressure is obtained by the increase of calibre. Rounds 3 and *19* also exhibit a good increase of penetration, but at the expense of some additional pressure.

This portion of the experiment may be briefly summed up in the statement that increasing the diameter of the bore by half-an-inch simply made a bigger gun of the piece; and, as might be expected, the big gun proved more powerful than the small one—the difference being obvious, even with so small an enlargement.

We now come to something more novel. The science of explosives, though it has made rapid progress during the last few years, is far from being thoroughly understood yet, and still possesses the charm of offering its votaries much untrodden ground to explore and many new facts and combinations to discover. No matter how simple the conditions, how thoroughly ascertained the component variables, a new experiment with gunpowder almost always yields some unexpected results; and I have now to relate how the power of the 80-ton gun was suddenly increased in a very remarkable degree.

As was pointed out in the previous paper on this subject, the great object of the artillerist is to diminish the maximum pressure of the gas on the surface of the bore to the lowest point consistent with good results as regards velocity, but to sustain this low maximum as long as possible. In fact, a gunner acquainted with his art would like a uniform pressure in the gun up to the moment of the shot's quitting the muzzle. When a cartridge is rammed home, and the projectile

presses against it, the action of the charge on ignition is to evolve its gas from the surface of the grains in the space behind the stationary shot till a pressure is established sufficient to push it away. It moves tardily at first, and as the powder continues to burn up rapidly in a slowly increasing space, the pressure rises and the shot moves faster. As soon as the increase of room behind overtakes the increase of evolution of gas, a momentary equilibrium is established, and then the pressure begins to fall again. With the large-grained cubical powders rammed up, the maximum pressure is usually reached when the shot has travelled about 6 ins.; and probably, except under abnormal circumstances, all pressures of importance arise after the motion of the shot has commenced, but before it has had time to travel far enough to relieve the tension of the gas.

When rammed up hard, the space occupied by the cubical powders is about 24·6 cub. ins. per pound, against 26·0 cub. ins. for pebble powder. If, now, we lengthen the cartridge by making it thinner, leaving an air space over the top of such an extent that the content of the space behind the projectile is in increased proportion to the weight of the charge, each pound of powder will have more room at first in which to burn up and evolve its gas, which will therefore never reach the same density as when the cartridge has been rammed home. The pressures and velocities will thus be reduced. This much has long been known, and many proposals have been made involving the use of air spaces. The experiments tried have, however, always failed; the start being rendered unpromising by the difficulty of obtaining a satisfactory velocity. Still, the principle of reducing the maximum pressure by an air space, and keeping up this low maximum as long as possible by increasing the amount of charge, appeared to be right; and the last experiments with the 80-ton gun indicate that the reason that success had not attended previous attempts in this direction was simply that the question had not been pushed far enough.

I believe that the researches made by Captain A. Noble, of Elswick, into the phenomena of the explosion of charges at different densities in closed vessels gave a stimulus to farther trials of air-spaced cartridges; and certain remarkable results obtained by the Germans (see Table B) caused the Committee on Explosives to make experiments of this character.

The Germans, as my readers are probably aware, use prismatic powder for their heavy guns—which are breech-loaders. The latest grain of prismatic powder is a cake with one hole through it; so that in burning the gas is evolved from both the inside and outside, and thus, while the outer surface diminishes, the inner increases. The evolution of gas is therefore more rapid than with our solid grains in the later stages of combustion. The projectiles for breech-loading guns have bands on them, larger than the lands, and have to be forced through the bore—requiring much greater pressure to start them than is the case, *cæteris paribus*, with muzzle-loaders, whose projectiles slip easily away, especially when the increasing twist is employed. From these two causes it appears probable that if air spaces are found beneficial, a larger proportionate air space would be necessary with

breech-loading than with muzzle-loading guns. Table B indicates pretty clearly that in the German experiments the density of about 35 cub. ins. to the pound of charge gave the best results in the gun of 56 tons. The most suitable air space for our service guns is not yet accurately known, but it appears fairly certain that the larger the calibre the less should be the density of the charge; because, as the weight of the projectile increases approximately with the cube of the diameter, while the surface of its base, exposed to the driving action of the gas, increases only as the square, greater pressure per square inch is required to set the bigger shot in motion, and it will move more slowly away, and will give more time for the density of the expanding gas behind it to increase.

TABLE B.

Krupp B.L. 33·5c (13·976-*in.*) *Gun.*

Experiments at Krupp's works, 27. 12. 75.

Round.	Description of powder.	Weight of charge.	Weight of projectile.	Space occupied by charge.				Energy per ton of pressure.	Muzzle velocity.	Pressure.	Energy.	
				Length.	Diameter.	Volume.						
						Total.	Per lb. of powder.				Total.	Per inch.
		lb.	lb.	ins.	ins.	c. ins.	c. ins.	ft. tons	ft.	tons.	ft. tons	ft. tons
1	Ordinary prismatic	176·4	1157·4	59·568	14·449	9767	55·37	553	1209	21·2	11727	267·1
2	Prismatic powder with one hole, 100 prisms weighing 8·377 lbs.	220·46	1155·2	59·213	14·449	9709	44·04	853	1360	17·4	14833	337·8
3	" "	242·5	1147·5	59·017	14·449	9677	39·90	923	1445	18·0	16609	378
4	" "	264·5	1145·3	58·978	14·449	9671	36·56	?	1517	?	18270	416
5	" "	275·6	1143·1	59·686	14·449	9787	35·51	794	1567	24·5	19457	443
6	" "	275·6	1139·8	59·174	14·449	9703	35·20	841	1565	23·0	19351	441
7	" "	275·6	1145·3	58·663	14·449	9619	34·90	874	1567	22·3	19494	444
8	" "	286·6	1146·4	59·017	14·449	9677	33·76	802	1595	25·2	20217	460
9	" "	297·6	1146·4	59·370	14·449	9735	32·71	822	1637	25·9	21295	485
10	Large grain from ·984 to 1·181 in...	297·6	1145·3	59·489	14·449	9755	32·77	965	1390	15·9	15340	349

After two or three preliminary rounds, the Committee on Explosives decided to fix upon 30 cub. ins. as the standard, and proceeded to carry out the next experiment with the gun in its 15-in. calibre on this basis.

Table C gives the particulars of the rounds fired under these new conditions.

The rounds are arranged in such order as to show clearly the series fired with each size of powder. As long as the usual method of ramming the shot and cartridge hard home was adhered to, the *best* result* had been obtained in round 9, when 220 lb. of 1·5-in. powder yielded nearly 21,000 ft. tons of energy with the moderate mean pressure of 23·3 tons behind the shot, while the maximum did not exceed 24·5 tons. The *highest* result had been given at round 3 by 230 lb. of 1·7-in. powder, when nearly 22,000 ft. tons of energy had been achieved; at the expense, however, of a mean pressure of 26·2 tons, the maximum reaching 27·6 tons per square inch—a pressure which artillerists consider too high for continuous firing and for the various

* *Vide* Table A.

liabilities of service. Nothing more could be got out of the rammed-up charges.

TABLE C.

Experiments with 80-*ton R.M.L. Gun. Expl. No.* $\frac{405}{2}$. *Calibre,* 15 *ins. Cartridges pressed to densities of about* 30 *cub. ins. per pound.*

Round.	Description of powder.	Charge. Weight.	Charge. Length after loading.	Charge. Cubical ins. per lb.	Projectile. Total weight.	Velocity. At muzzle.	Velocity. At 1000 yds.	Maximum pressure.	Mean pressure on powder chamber, A, 1, 2, and 3 gauges.	Energy. Total. Theoretic.	Energy. Total. Realised.	Energy. Per pound of powder.	Energy. Per ton of mean pressure on pdr. chamb.	Factor of effect.	Energy. Total. At the muzzle.	Energy. Total. At 1000yds.	Energy. Per inch of shot's circumference. At the muzzle.	Energy. Per inch of shot's circumference. At 1000yds.
		lb.	ins.	c. ins.	lb.	f.s.	f.s.	ft. tons per square inch.	ft. tons per sq. in.	ft. tons.	ft. tons.	ft. tns.	ft. tons.	per cent.	ft. tons.	ft. tons.	ft. tons.	ft. tons.
10	Cubical, 30. 9. 75 / 2. 12. 75 mixed. 1·5-in. edge.	230	40·50	29·6	1266	1536	1421	21·2 at A	18·9	23,005	20,705	90·0	1095·0	90·0	20,705	18,134	439	385
11		240	45·00	31·7	1266	1518	1404	19·4 at A	18·9	23,589	20,222	84·2	1075·0	85·7	20,222	17,290	429	367
12		240	44·75	31·5	1466	1430	1338	19·9 at A	19·4	23,589	20,781	86·6	1071·0	88·0	20,781	18,193	441	386
13	" "	250	44·25	30·0	1466	1464	1369	21·5 at A	20·8	24,200	21,686	86·7	1042·0	89·6	21,686	19,046	460	404
14	" "	260	46·00	30·0	1472	1470	1376	21·6 at A	20·9	24,830	22,005	84·8	1055·0	88·6	22,005	19,320	467	410
21	Cubical, No. 7, 1·5-in. edge.	250	44·25	30·0	1464	1451	1357	21·1 at A	20·5	24,250	21,316	85·2	1044·0	88·2	21,316	18,714	456	399
23		260	46·00	30·0	1466	1474	1378	21·8 at 1	20·7	24,850	22,080	84·9	1066·2	88·8	22,080	19,297	471	412
25		270	47·75	30·0	1466	1491	1394	22·6 at A	21·6	25,460	22,592	83·7	1046·8	88·7	22,592	19,747	482	421
27	"	280	49·50	30·0	1466	1501	1403	21·8 at 4	21·2	26,040	22,895	81·8	1080·0	87·9	22,895	20,004	489	427
30	"	290	51·35	30·0	1466	1511	1413	23·4 at A	22·4	26,593	23,205	80·0	1036·0	87·3	23,205	20,290	495	433
32	"	300	52·80	30·0	1466	1540	1440	26·0 at A	22·6	27,390	24,100	80·3	1066·0	88·0	24,100	21,072	514	450
26	"	303·3	49·50	27·7	1466	1555	1454	24·8 at 2	24·1	27,491	24,517	80·9	1017·3	89·5	24,517	21,484	523	458
8	Cubical, same dates as Rd. 10. 1·7-in. edge.	230	42·00	30·8	1466	1408	1318	22·0 at A	21·5	23,005	20,146	87·6	937·0	87·5	20,146	18,065	427	383
15	Cubical, 5. 2. 76 / 8. 3. 76 mixed. 1·7-in. edge.	250	44·25	30·0	1465	1459	1364	22·2 at 1	21·6	24,250	21,633	86·5	1002·0	89·2	21,633	18,907	462	403
17		260	46·00	30·0	1466	1466	1371	22·5 at 3 and 4	22·2	24,850	21,840	84·0	983·8	87·9	21,840	19,102	466	407
19		270	47·75	30·0	1466	1484	1388	23·1 at A	22·3	25,460	22,380	82·9	1003·0	87·9	22,380	19,578	477	417
22	" "	280	49·50	30·0	1466	1495	1398	23·5 at 1	22·7	26,040	22,713	81·1	1000·0	87·2	22,713	19,861	484	424
28	" "	290	51·20	30·0	1466	1515	1416	26·7 at A	24·0	26,593	23,325	80·4	972·0	87·7	23,325	20,375	498	435
16	Do., do., 2·0-in.	250	44·25	30·0	1466	1408	1318	20·9 at 4	20·7	24,250	20,146	80·6	995·9	83·1	20,146	17,654	429	376
18	" "	260	46·00	30·0	1466	1423	1331	21·3 at 1 and 2	20·6	24,850	20,576	79·1	998·9	82·8	20,576	18,008	439	384
20	" "	270	47·75	30·0	1466	1440	1347	21·2 at A and 1	20·7	25,460	21,073	78·0	1018·0	82·7	21,073	18,439	449	393
24	" "	280	47·75	29·0*	1466	1456	1362	23·1 at 1	21·7	26,040	21,543	76·9	992·8	82·7	21,543	18,852	459	402
29	" "	290	51·35	30·0	1466	1480	1384	23·9 at A	21·9	26,593	22,260	76·8	1016·0	83·7	22,260	19,466	475	415
31	" "	300	52·85	30·0	1466	1494	1397	24·0 at A	22·0	27,390	22,682	75·6	1031·0	82·8	22,682	19,833	484	423

* In round 24, shot accidentally rammed too far.

As was expected, the increase of the space in which the charge was ignited at once caused both the velocities and pressures to drop, and the question was which would rise first as the charge was successively added to. Comparing round 10 with round 9, we see that the increase of space caused a loss of 10 ft. in the velocity, while the mean pressure dropped 4½ tons. It is true that 10 lb. more powder were used, but this is of little consequence: as has been previously stated, the real criterion is the ratio of velocity (or penetration) to pressure. Increasing the charges of 1·5-in. powder to 260 lb., and using the heavy shot, we see that 22,000 tons of energy are obtained, at a cost of barely 21 tons mean pressure. This is obviously a great improvement on round 3, fired with 1·7-in. cubes. At this point the brand of 1·5-in. cubes hitherto used in this experiment was exhausted, and another brand was taken. Comparing rounds 21 and 23, fired with the new brand, with rounds 13 and 14 with the old one, but little difference in quality is perceptible, and practically the powders may be considered equal. The experiment was continued, and the charges were increased to 300 lb., the space of 30 cub. ins. to the pound being preserved. With 300 lb. the fine result of 24,100 tons energy at a cost of 22·6 tons mean pressure behind the shot was obtained; but a slight wave action was perceptible, and it became apparent that the cartridge—which now attained the length of 52·8 ins.—could not be much farther elongated without risk of setting up that inconvenient vibratory motion of the gas which is the *bête noire* of the gunner.

Round 26 deserves special notice. It had been intended to fire 280 lb., but by mistake an extra weighing of 23·3 lb. was placed in the cartridge, which was then compressed into the space allotted to the 280-lb. charge. The powder, therefore, had barely 28 cub. ins. per pound in which to expand, and the remarkable energy of 24,517 ft. tons was realised. The mean pressure, as might be expected, was high; but no trace of wave action was perceptible, and the limits laid down by the Committee were not exceeded. Had circumstances permitted, it would probably have been thought advisable to have pursued the experiment into the complicated question of varying air spaces with each charge; but time pressed, and the expense of trials of this magnitude is too great to permit the entire elucidation of all the knotty points which present themselves to the enquirer during a lengthened experiment of so novel a character.

Proceeding *pari passu* with the 1·5-in. cubes, the 1·7-in. and 2·0-in. powders had been fired in successively increasing charges; but a study of the table given above will show that they had not proved equally successful, and it is not necessary for me to dilate on the peculiarities of the series fired with them.

At this point we appear to have reached the limit of power to be realised in the 15-in. calibre, even when increased by the contrivance of an air space of 30 cub. ins. per pound of charge. We have now to consider another device containing still more novelty, and destined in all probability to play a part of great importance in the history of artillery of all sizes. If we turn back to Table A, we see that round 4 was fired with 250 lb. of 2-in. powder, rammed up, and that the

length of the cartridge was 36·5 ins. Comparing this with round 16, Table C, we observe that the length of a 250-lb. charge, air-spaced to 30 cub. ins., is 44·2 ins.—the difference being rather more than half a calibre. This lengthening of the cartridge is of course equivalent to shortening the gun by that amount, as far as the travel of the shot is concerned. A very sensible loss of velocity is thus occasioned, and it would evidently be desirable to afford more room for the charge inside the bore. To accomplish this it is necessary to enlarge the chamber,* so that the cartridge can be shortened, and the enormous and inconvenient length required for heavy charges lessened. A reference to Table C will show that with 300-lb. charges in a 15-in. calibre this length reaches nearly 53 ins. Accordingly it was determined to take the 80-ton gun back to the boring machine and to enlarge its chamber. The gun was originally constructed with a view to its being bored out to a 16-in. calibre, and hence there could be no difficulty or risk in carrying the chamber to that size, while leaving the portion of the bore in front of the cartridge at a diameter of 15 ins. Of course this enlargement was not so great as could be desired; but it was thought that if the principle was correct, sufficient indication of its beneficial action would be obtained.

The enlarged portion of the bore was 40 ins. long, and was capable of holding 263 lb. at the rate of 30 cub. ins. to the pound, or 320 lb. fulled rammed up. It subsequently proved that it would have been better to have made the chamber a few inches longer; but this was not foreseen, and too much time would have been lost in removing the gun back to the factory and continuing the enlargement for a greater length, so as to suit the larger charges fired toward the end of the experiment.

It was determined to begin with charges of 260 lb. with each of the cubical powders allotted to the trials, and to increase this amount successively by 10 lb. at a time. Each cartridge was to be pressed to the mouth of the chamber—*i.e.*, to 40 ins.—and thus as the charge was increased the air space was diminished; so that, had the pressures permitted it, the chamber would have been eventually filled with a rammed-up cartridge.

Table D gives the particulars of the rounds fired under these conditions. The comparative rounds fired in the same calibre but in the unchambered state are added in italics beneath those of similar character, and the order adopted is that naturally given by the several powders tried.

The proposed arrangement of preserving equal lengths for the cartridges was adhered to for nine rounds, after which it was decided to return to the 30 cub. in. air space. Examining rounds 33, 34, and 35, each fired with 260 lb. of the brands before used, and comparing them with rounds *23*, *17*, and *18* respectively, it appears that in each case the

* A sketch of the origin and progress of the principle of applying an enlarged chamber to muzzle-loading ordnance in order to gain increased power, will shortly be given in a paper by the present writer on the new experimental field guns, which are constructed on this method, as proposed in 1873 by Br.-Gen. Campbell (then Superintendent of the Royal Gun Factories).

TABLE D.

Experiments with 80-*ton R.M.L. Gun. Expl. No.* $\frac{405}{2}$. *Calibre,* 15 *ins. Chambered to* 16 *ins. Comparative rounds in unchambered bore in italics.*

Round.	Description of powder.	Charge. Weight.	Charge. Length after loading.	Charge. Cubical ins. per lb.	Projectile. Total weight.	Velocity At muzzle.	Velocity At 1000 yds.	Maximum pressure.	Mean pressure on powder chamber, A, 1, 2, and 3 gauges.	Energy. Total. Theoretic.	Energy. Total. Realised.	Energy. Per pound of powder.	Energy. Per ton of mean pressure on pdr. chamb.	Factor of effect.	Energy. Total. At the muzzle.	Energy. Total. At 1000yds.	Energy. Per inch of shot's circumference. At the muzzle.	Energy. Per inch of shot's circumference. At 1000yds.
		lb.	ins.	c. ins.	lb.	f.s.	f.s.	ft. tons per square inch.	ft. tons per sq. in.	ft. tons.	ft. tons.	ft. tns.	ft. tons.	per cent.	ft. tons.	ft. tons.	ft. tons.	ft. tons.
33	1·5-in. No. 7.	260	40·0	30·29	1465	1480	1384	20·9 at A	20·4	24,960	22,245	85·6	1090·0	89·1	22,245	19,453	475	415
23	*Cubical, No. 7, 1·5-in. edge.*	*260*	*46·0*	*30·0*	*1466*	*1474*	*1378*	*21·8 at 1*	*20·7*	*24,850*	*22,080*	*84·9*	*1066·2*	*88·8*	*22,080*	*19,297*	*471*	*412*
36	" "	270	40·0	29·19	1466	1499	1402	22·5 at A	21·6	25,623	22,834	84·6	1057·0	89·1	22,834	19,975	487	426
25	" "	*270*	*47·75*	*30·0*	*1466*	*1491*	*1394*	*22·6 at A*	*21·6*	*25,460*	*22,592*	*83·7*	*1046·8*	*88·7*	*22,592*	*19,747*	*482*	*421*
39	" "	280	40 0	28·13	1471	1534	1435	23·2 at A and 2	22·7	26,208	23,998	85·7	1057·0	91·6	23,998	20,998	512	448
27	" "	*280*	*49·5*	*30·0*	*1466*	*1501*	*1403*	*21·8 at 4*	*21·2*	*26,040*	*22,895*	*81·8*	*1080·0*	*87·9*	*22,895*	*20,004*	*489*	*427*
42	" "	290	44·7	30·0	1466	1524	1425	22·3 at A	21·7	26,767	23,603	81·4	1088·0	88·2	23,603	20,635	504	440
30	" "	*290*	*51·35*	*30·0*	*1466*	*1511*	*1413*	*23·4 at A*	*22·4*	*26,393*	*23,205*	*80·0*	*1036·0*	*87·3*	*23,205*	*20,290*	*495*	*433*
45	" "	300	46·4	30·0	1466	1526	1427	22·6 at 1	22·0	27,360	23,665	78·9	1076·0	88·4	23,665	20,674	505	441
32	" "	*300*	*52·8*	*30·0*	*1466*	*1540*	*1440*	*26·0 at A*	*22·6*	*27,390*	*24,100*	*80·3*	*1066·0*	*88·0*	*24,100*	*21,072*	*514*	*450*
48	" "	310	48·1	30·0	1465	1553	1453	23·3 at A	22·5	27,931	24,493	79·0	1089·0	87·7	24,493	21,444	523	457
51*	" "	300	46·4	30·0	1472	1532	1433	24·4 at 1	24·1	27,360	23,950	79·8	994·0	87·5	23,950	20,955	511	447
49	1·5-in. S.C. 6.	300	46·4	30·0	1465	1535	1436	23·3 at A	22·3	27,360	23,930	79·8	1073·0	87·5	23,930	20,940	510	447
53	" "	310	48·1	30·0	1469	1551	1451	24·4 at A	22·8	27,931	24,496	79·0	1074·0	87·7	24,496	21,445	523	457
34	1·7-in. (5. 2. and 8. 3. 76.)	260	40·0	30·29	1466	1473	1377	21·5 at A	21·0	24,960	22,050	84·8	1050·0	88·3	22,050	19,269	470	411
17	*Cub. (5. 2. & 8. 3. 76. mixed) 1·7-in. edge.*	*260*	*46·0*	*30·0*	*1466*	*1466*	*1371*	*22·5 at 3 and 4*	*22·2*	*24,850*	*21,840*	*84·0*	*983·8*	*87·9*	*21,840*	*19,102*	*466*	*407*
37	" "	270	40·0	29·19	1466	1488	1392	22·5 at A	22·2	25,623	22,500	83·3	1014·0	87·8	22,500	19,690	480	420
19	" "	*270*	*47·75*	*30·0*	*1466*	*1484*	*1388*	*23·1 at A*	*22·3*	*25,460*	*22,380*	*82·9*	*1003·0*	*87·9*	*22,380*	*19,578*	*477*	*417*
40	" "	280	40·0	28·13	1468	1509	1411	24·7 at A	23·5	26,208	23,172	82·8	986·0	88·4	23,172	20,214	494	431
22	" "	*280*	*49·50*	*30·0*	*1466*	*1495*	*1398*	*23·5 at 1*	*22·7*	*26,040*	*22,713*	*81·1*	*1000 0*	*87·2*	*22,713*	*19,861*	*484*	*424*
43	" "	290	44·7	30·0	1466	1522	1423	23·0 at A	22·4	26,767	23,540	81·2	1051·0	87·9	23,540	20,576	502	439
28	" "	*290*	*51·2*	*30·0*	*1466*	*1515*	*1416*	*26·7 at A*	*24·0*	*26,593*	*23,325*	*80·4*	*972·0*	*87·7*	*23,325*	*20,375*	*498*	*435*
46	" "	300	46·4	30·0	1466	1531	1432	23·2 at A	22·9	27,360	23,820	79·4	1040·0	89·0	23,820	20,837	508	445
50	" "	310	48·1	30·0	1466	1551	1451	24·5 at A	23·2	27,931	24,446	78·9	1054·0	87·5	24,446	21,395	522	456
52*	" "	290	44·7	30·0	1466	1521	1422	23·0 at 2 and 3	22·2	26,767	23,510	81·0	1059·0	87·8	23,510	20,550	502	428
35	2-in. (5. 2. & 8. 3. 76.)	260	40·0	30·29	1472	1424	1332	21·5 at A	20·5	24,960	20,690	79·6	1009·0	82·9	20,690	18,104	441	386
18	*Cub. (5. 2. & 8. 3. 76. mixed) 2-in. edge.*	*260*	*46·0*	*30·0*	*1466*	*1423*	*1331*	*21·3 at 1 and 2*	*20·6*	*24,850*	*20,576*	*79·1*	*998·9*	*82·8*	*20,576*	*18,008*	*439*	*384*
38	" "	270	40·0	29·19	1472	1446	1352	22·5 at A	21·3	25,623	21,330	79·0	1002·0	83·2	21,330	18,652	455	398
20	" "	*270*	*47·75*	*30·0*	*1466*	*1440*	*1347*	*21·2 at A and 1*	*20·7*	*25,460*	*21,073*	*78·0*	*1018·0*	*82·7*	*21,073*	*18,439*	*449*	*393*
41	" "	280	40·0	28· 3	1466	1462	1367	22·6 at A	21·9	26,208	21,720	77·6	992·0	82·9	21,720	18,990	463	405
24†	" "	*280*	*47·75*	*29·0*	*1466*	*1456*	*1362*	*23·1 at 1*	*21·7*	*26,040*	*21,543*	*76·9*	*992·8*	*82·7*	*21,543*	*18,852*	*459*	*402*
44	" "	290	44·7	30·0	1466	1474	1378	21·1 at 2	20·9	26,767	22,080	76·1	1056·0	82·5	22,080	19,296	471	412
29	" "	*290*	*51·35*	*30·0*	*1466*	*1480*	*1384*	*23·9 at A*	*21·9*	*26,593*	*22,260*	*76·8*	*1016·0*	*83·7*	*22,260*	*19,466*	*475*	*415*
47	" "	300	46·4	30·0	1466	1475	1379	21·7 at 1	21·3	27,360	22,109	73·7	1038·0	82·6	22,109	19,325	472	412
31	" "	*300*	*52·85*	*30·0*	*1466*	*1494*	*1397*	*24·0 at A*	*22·0*	*27,390*	*22,682*	*75·6*	*1031·0*	*82·8*	*22,682*	*19,833*	*484*	*423*

* Fired with axial vent. † In round 24, shot accidentally rammed too far.

enlargement of the chamber has caused a slight increase of work realised, accompanied by a small diminution of pressure. The increase of energy is probably due chiefly to the additional 6 ins. of travel of shot gained, while the diminution of pressure arises from the more compact and favourable shape of the cartridge. The 1·5-in. cubes still preserve their superiority.

Turning now to rounds 36, 37, and 38, fired with 270 lb. each, we see that the increase of 10 lb. in the constant length 40 ins. has reduced the air space to little more than 29 cub. ins. per pound. This has slightly raised the pressures, and these are now equal with those recorded in the comparative rounds *25, 19,* and *20*. The velocities are slightly in excess in the chambered bore.

We next come to rounds 39, 40, and 41, fired with 280 lb. each. Here the air space is reduced nearly down to 28 ins. per pound—which is about the density of a rammed-up charge of R.L.G. powder. The mean pressures at once ascend, and in each case surpass those obtained in the comparative rounds *27, 22,* and *24*. An increase of velocity—very marked with the 1·5-in. cubes—was also gained. It will be observed that in the comparative round *24* the charge had accidentally been compressed to a density of 29 cub. ins. per pound; so that the air spaces are about equal. Here the pressures also are practically about equal, and we simply gain the trifling increment of 6 ft., due to the lengthening of the travel of the shot by 7·75 ins.

The increase of the pressures offered a distinct warning that the true road to improvement did not lie in the direction of filling up the chamber; and accordingly the density of 30 cub. ins. per pound was returned to, and retained till the conclusion of the experiment. Since the cartridge now protruded considerably from the chamber into the bore, a portion of the beneficial action of the principle was sacrificed, but enough remained for the purposes of preliminary experiment.

The 290-lb. charges were fired with a density of 30 cub. ins. to the pound, and it will be seen that in each instance the pressures dropped 1 ton, or nearly 5 per cent., on the square inch; while the energy extracted from the powder rose in two cases out of three, and in each round the ratio of work done to pressure was increased.

The 300-lb. charges show a similar increase in this ratio; but the firing was postponed on account of excessive rain, and the cartridges probably absorbed an unusual amount of moisture, and therefore gave somewhat low results, both in velocity and pressure.

The 310-lb. charges, fired under ordinary atmospheric conditions, with the 1·5 and 1·7-in. cubes, yielded very fine ballistic results. Round 48 was the best ever fired up to the date of the experiment. An energy of 24,493 ft. tons with a maximum pressure of 23·3 tons and a mean pressure in the powder-chamber of 22·5 tons per square inch was better than anything yet obtained from the 80-ton gun, and very far beyond any result realised elsewhere. It did not appear at this stage desirable to continue the experiment farther in the direction of increase of charge, and the gun, having been examined and found none the worse for its efforts, was returned to the boring machine, that its calibre might be again enlarged—this time to a diameter of 16 ins. On completion of this alteration, the bore once more became cylindrical

throughout, the chamber principle being held in abeyance as a future development.

The projectiles manufactured for the new calibre weighed just 1703 lb., including the gas-check, being 237 lb. heavier than those fired from the 15-in. calibre. Since the powder-chamber had already been enlarged to 16 ins. and a proportionate charge had been fired, it was clear that a velocity equal to that previously obtained could not be expected with a shot so much heavier. Still, a gain in energy was anticipated, on account of the larger base on which the gas would act, or, as Captain A. Noble puts it, on account of the greater space within the gun in which the gas could expand and do work. The penetrating power at 1000 yds. would, it was thought, be diminished by the alteration, unless means could be adopted to obtain a higher velocity than calculation showed to be probable if the charges were burnt under the same conditions as before.

Table E furnishes particulars of the rounds fired in the 16-in. calibre.

In view of the great increase in the weight of the projectile, the charges began as low as 250 lb., and were increased by 10-lb. stages to 300 lb., the results being exactly as anticipated—that is, a less velocity, a higher energy, and a lower penetrating power were given by round 6 of Table E than by round 45 of Table D; and the same may be said of each round capable of comparison. The pressures were practically equal in the two calibres.

It was now thought desirable to try the effect in the enlarged bore of increasing the space occupied by the cartridges, and they were farther lengthened till the portion of the bore behind the projectile contained 32 cub. ins. for each pound of powder instead of 30 cub. ins. Rounds 7 to 16 and round 19 show that this addition to the air-space permitted a considerable increase to the charge, which rose to 350 lb., while a farther enlargement of the air-space to 34 cub. ins. enabled the Committee to venture on the vast charge of 370 lb.—the largest ever fired as yet. A glance at the table will show that the work done by 350 lb. with 32 cub. ins. volume per pound is about equal to that performed by 370 lb. with 34 cub. ins. volume, and an attentive consideration of the successive rounds appears to lead to the conclusion that the results rise steadily up to the point of 32 cub. ins. volume, and rather exhibit a tendency to fall off in progressiveness after 34 cub. ins. A few rounds will probably be fired to determine whether 33 cub. ins. and a charge of 360 or 370 lb. will not just reach the top of the curve, and give the maximum effect attainable. At any rate, we have now arrived at a higher point than we had reached previously, and have beaten round 48, both in energy and penetration; that is, we can drive a bigger shell through a thicker plate than we could before. Still, we cannot afford to rest and be thankful, for probably it will not be long before farther progress will become inevitable, if we are to retain the lead. Sir W. Armstrong's 100-ton M.L. guns, with a calibre of 17 ins., firing a shot of 2000 lb., are guaranteed to yield energy equal to 25,000 ft. tons; and as the bores will be of great length and the velocity required to produce this effect will be only 1343 f.s., there is little doubt that the guarantee will be largely surpassed. Krupp is said to be constructing a breech-loader to weigh

150 tons; and it is certain that unless we are content to be beaten, we must build something bigger than anything we now have.

TABLE E.

Experiments with 80-*ton R.M.L. Gun. Expl. No.* $\frac{405}{3}$. *Calibre* 16 *ins.*

Date of firing 24, 25, and 26. 7. 76.

Round.	Description of powder.	Charge.			Projectile. Total weight.	Velocity.		Maximum pressure.	Mean pressure on powder chamber.	Energy.				Factor of effect.	Energy.			
										Total.					Total.		Per inch of shot's circumference.	
		Weight.	Length after loading.	Cubical ins. per lb.		At muzzle.	At 1000 yds.			Theoretic.	Realised.	Per pound of powder.	Per ton of mean pressure on pdr. chamb.		At the muzzle.	At 1000 yds.	At the muzzle.	At 1000 yds.
		lb.	ins.	c. ins.	lb.	f.s.	f.s.	ft. tons per square inch.	ft. tons. per sq. in.	ft. tons.	ft. tons.	ft. tns.	ft. tons.	per cent.	ft. tons.	ft. tons.	ft. tons.	ft. tons.
1	W.A. 1·5-in., cubical No. 7	250	38	30	1703	1384	1298	21·6 at 3	21·0	25,225	22,613	90·4	1077	89·7	22,613	19,890	452	398
2	" "	260	39·5	30	"	1396	1308	21·0 at 2	20·7	25,480	23,007	88·7	1111	90·3	23,007	20,200	460	404
3	" "	270	41	30	"	1411	1322	22·0 at A	21·3	26,600	23,503	87·0	1103	88·4	23,503	20,630	470	413
4	" "	280	42·5	30	"	1426	1336	21·2 at A and 2	21·2	27,270	24,006	85·7	1132	88·0	24,006	21,070	480	421
5	" "	290	44	30	"	1452	1360	23·1 at A	22·0	27,870	24,890	85·8	1132	89·3	24,890	21,835	498	437
6	" "	300	46	30	"	1458	1366	23·0 at A	21·5	28,500	25,095	83·7	1167	88·0	25,095	22,030	502	440
7	" "	300	48·4	32	"	1442	1350	21·0 at A	20·0	28,500	24,548	81·8	1227	86·1	24,548	21,515	491	430
8	" "	310	50	32	"	1462	1369	22·0 at A and 1	21·3	29,110	25,233	81·4	1185	86·7	25,233	22,125	504	442
9	" "	320	51·6	32	"	1469	1375	22·3 at A	21·3	29,660	25,475	79·6	1196	85·9	25,475	22,320	509	446
10*	" "	300	48·4	32	"	1437	1347	21·1 at 1*	20·2	28,500	24,377	81·3	1207	85·5	24,377	21,420	487	428
11	" "	330	53·2	32	"	1479	1383	21·7 at A	20·6	30,230	25,823	78·3	1253	85·4	25,823	22,580	516	452
12	" "	340	54·8	32	"	1494	1394	22·4 at A	21·5	30,840	26,350	77·5	1226	85·4	26,350	22,900	527	460
13*	" "	320	51·6	32	"	1472	1376	21·0 at 1*	20·3	29,660	25,580	79·9	1260	86·2	25,580	22,350	511	447
14*	" "	340	54·8	32	"	1486	1388	21·3 at 1*	20·1	30,840	26,030	76·6	1297	84·4	26,030	22,740	520	455
15	" "	350	56·4	32	"	1505	1405	21·8 at A	20·4	31,325	26,740	76·4	1311	85·4	26,740	23,300	535	466
16*	" "	350	56·4	32	"	1502	1402	21·4 at 1*	20·3	31,325	26,630	76·1	1312	85·0	26,630	23,200	532	464
19	" "	350	56·4	32	"	1493	1394	22·8 at A	21·0	31,325	26,314	75·2	1253	84·0	26,314	22,835	526	457
17	" "	350	59·9	34	"	1467	1372	20·7 at A	19·6	31,325	25,406	72·6	1296	81·1	25,406	22,220	508	444
18*	" "	350	59·9	34	"	1475	1379	29·6 at 1*	18·4	31,325	25,683	73·4	1396	82·0	25,683	22,450	514	449
20*	" "	360	61·6	34	"	1487	1389	19·7 at 1*	18·8	31,930	26,103	72·5	1388	81·8	26,103	22,775	522	455
21*	" "	370	63·2	34	"	1495	1396	21·5 at 1*	19·9	32,410	26,385	71·3	1326	81·4	26,385	23,000	528	460

* Fired by axial vent, but ignited at service distance from end of bore.

Still, the 80-ton gun is by no means a bad weapon, as far as it goes; and we will now consider its powers as realised up to the present stage with relation to the problem originally propounded to the designers, and observe how its prowess has been gradually augmented at each successive stage of its development.

TABLE F.

Round.	Calibre.	Maximum pressure.	Mean pressure.	Total energy.	Penetrating power at 1000 yds.
	ins.	ft. tons.	ft. tons.	ft. tons.	ft. tons.
17	14·5	24·9	23·0	20,058	380
6	15·0	24·8	23·8	20,705	383
30	15·0*	23·4	22·4	23,205	433
48	15·0†	23·3	22·5	24,493	457
15	16·0*	21·8	20·4	26,740	466

* Air spaced. † Air spaced and chambered.

These rounds have been selected as the highest in power at each stage which could be fixed upon as service rounds—that is, in which no pressures of an inadmissible character are recorded.

For purposes of experiment, where the brands of powder are intimately known and their variations can be depended on not to exceed safe limits, it is convenient to consider rather the mean pressure in the chamber than an isolated maximum; but for firing under service conditions this method of observation would not be admissible, and hence I have discarded it in the above summary. The last column shows that the great stride in the progress of the gun's powers has been made by the introduction of the air-space principle. The other novelty —the enlargement of the chamber—has also gained great success, when it is considered that the increase of diameter was too small, and moreover that the chamber was too short to permit the full development of the principle.

It is in contemplation to enlarge the chamber to a diameter of 18 ins. on the return of the gun from Shoeburyness, where it will speedily exhibit its powers in a practical manner; but time presses, and this farther development cannot be carried out at present. In the meanwhile, taking round 15 (Table F) as our best result, and bearing in mind that with our present knowledge of powder there is no difficulty in repeating any result once gained without sensible difference, we proceed to investigate the question of penetration. Working out the two formulæ adopted in the previous paper on this subject as types, it appears that at 1000 yds. the 1703-lb. projectile will perforate according to

	ins.
Capt. English, R.E.	20·1
Major Noble, R.A.	26·1

Since Capt. English's results are more in favour of the armour than those obtained by any other mode of calculation at present in use, it appears probable that the gun can now perform the task allotted to it, and I venture to think that it may confidently be trusted to do all that is asked of it, and a little to spare, in its final development, if it should be found desirable and convenient to increase its power yet farther.

SEPTEMBER 4TH, 1876.

TRACTION.

[No. II.]

BY

MAJOR W. KEMMIS, R.A.

In order to calculate the load which a horse may fairly be called upon to move, it is necessary, first, to lay down the average speed at which he is required to travel, and the average nature of ground over which he has to pass.

As pointed out in a previous paper on Traction,* the *average* nature of ground which field artillery has to manœuvre upon may be considered to be that which opposes an average obstacle or resistance to rolling whose height is equivalent to a slope of $6\frac{1}{2}°$.

The *average* pace of manœuvre is the "trot, regulated with reference to the slowest horse,"† which may be taken as meaning a speed of 7 miles an hour for horse artillery and 6 miles an hour for field batteries.

A good draught horse, it is considered, moving at the former speed, can exert an *average*‡ tractive force of 70 lbs., and at the latter a force of 82 lbs.—the duration of labour being from 4 to 5 hours.§

The tractive power of a team is not directly proportional to the number of horses in it; in fact, it has been asserted that no more than six horses can usefully be employed in a team, if much speed is required.

Assuming, however, that the full power of the individual units is obtainable from a team of six horses, when well trained and well

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* "Proceedings, R.A. Institution," Vol. IX. p. 138.

† "Manual of Field Artillery Exercises," 1875.

‡ "He adapts himself admirably to his work, increasing or diminishing his efforts according to the variations of draught—resting himself, as it were, and acquiring vigour where his utmost strength is not called for; and thus becomes enabled to make exertions far beyond his *average* strength where any obstruction is to be overcome."—Youat on the Horse.

§ Rankine, in his "Manual of Civil Engineering," gives a tractive force of 64 lbs. for a speed of $7\frac{1}{2}$ miles per hour, and 96 lbs. for 5 miles per hour, in each case working 4 hours a day.

Tredgold, in his work on Railways, gives 83 lbs. for a speed of 4 miles per hour and 62·5 lbs. for 5 miles per hour, in each case the duration of labor being 6 hours; and states that if the hours of labor be lessened, the velocity may be raised much higher.

Youat concludes that when 6 or 8 miles per hour is required, the day's work should be 5 or 6 hours and the draught 80 to 100 lbs.

driven, we have the total tractive force of a gun-team for horse artillery as $70 \times 6 = 420$ lbs.

For a gun-team of six horses for a field battery, we have $82 \times 6 = 492$ lbs., and for a gun-team of eight for the same (making a deduction of 25 per cent. for the additional pair of horses) $82 \times 8 - 41 = 615$ lbs.

The relation between the tractive force and the load, on level ground, is given by the equation*

$$P = \frac{r \,.\, \mu \,.\, W \,.\, \cos \epsilon}{R} + (W + W') \sin \epsilon, \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\text{or } W = \frac{R\,(P - W' \sin \epsilon)}{r \,.\, \mu \,.\, \cos \epsilon + R \,.\, \sin \epsilon}; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where P = tractive force in lbs., in the direction of the traces,
W = weight of carriage body and load in lbs.,
W' = weight of wheels,
r ($= AC'$*) = mean radius of axle-arm in inches,
R ($= C'B$*) = mean radius of wheel in inches,
μ = coefficient of friction between wheel and axle,
ϵ = angle of slope due to height of obstacle.

In field artillery carriages, $W' = 1015$ lbs., $r = 1{\cdot}38''$, $R = 29{\cdot}937''$, while μ may be taken as ·01; and for ground opposing an average resistance to rolling, as already stated, $\epsilon = 6\frac{1}{2}°$.

Inserting the above values, and making $P = 420$ in equation (2), we get the total load, or weight of carriage complete with its load proper, which a gun-team of six horses should, for horse artillery, be required to draw, thus:—

$$W = \frac{29{\cdot}937\,(420 - 1015 \times {\cdot}1132)}{1{\cdot}38 \times {\cdot}01 \times {\cdot}9935 + 29{\cdot}937 \times {\cdot}1132}$$
$$= 2693 \text{ lbs.},$$
$$\text{and } W + W' = 3708 \text{ lbs.}$$
$$= 33 \text{ cwt. } 0 \text{ qrs. } 12 \text{ lbs., total load.}$$

In the same manner, making $P = 492$, we find for a gun-team of six horses for a field battery,

$$W = 3328 \text{ lbs.},$$
$$\text{and } W + W' = 4343 \text{ lbs.}$$
$$= 38 \text{ cwt. } 3 \text{ qrs. } 3 \text{ lbs., total load;}$$

and making $P = 615$ for a team of eight horses for the same,

$$W = 4414 \text{ lbs.},$$
$$\text{and } W + W' = 5429 \text{ lbs.}$$
$$= 48 \text{ cwt. } 1 \text{ qr. } 25 \text{ lbs., total load.}$$

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* See "Traction," "Proceedings, R.A. Institution," Vol. IX. p. 138.

From the foregoing, it appears that the load which each horse should be required to draw is

618·0 lbs. for horse artillery,
723·8 lbs. for light field batteries,
678·6 lbs.* for heavy field batteries.

This Decker† lays down as

500·0 lbs. for horse artillery,
650·0 lbs. for foot artillery;

adding that these are less than they actually would be on service; while Migout and Bergery, in their "Essay on Gun-carriages," give the following as the weight which each horse can draw under all circumstances of war:—

743·2 lbs. for light field batteries,
878·4 lbs. for field parks.

The ratio‡ of the tractive force to the total load, calculated by equation (2), or $\frac{P}{W+W'}$, averages $\frac{1}{8\cdot74} = \cdot11441 =$ the tangent of an angle of 6° 32′, nearly; and thus is in agreement with the statement in the "Mathematical Course" that "the tangent of the inclination of the traces should equal the ratio of the traction to the load"—the angle of inclination of the traces being 6° 30′, upon which, as mentioned in the former paper, the average resistance to rolling is based.

To compare, now, the load calculated that each gun-team should draw with that which it actually has to draw, we have—

	cwts.	qrs.	lbs.	
Horse artillery ...	37	1	10	actual total load,§
	33	0	12	calculated "
	4	0	26	difference.
Light field battery,	42	0	24	actual total load,‖
	38	3	3	calculated "
	3	1	21	difference.
Heavy field battery,	50	1	9	actual total load,¶
	48	1	25	calculated "
	1	3	12	difference.

* Less than in the case of light batteries, on account of the loss assumed for the larger number of horses driven together.

† "Principles and Practice of Modern Artillery," Lieut.-Colonel Owen, R.A.

‡ This ratio has been variously estimated. Rankine gives it as $\frac{1}{15}$ on gravel road and $\frac{1}{7}$ on soft, sandy, and gravelly ground; Youat as $\frac{1}{25}$ on road in good repair; while Migout and Bergery state that in 1825, at Metz, it was found to be $\frac{1}{22}$ over fine turf and $\frac{1}{10}$ over recently ploughed and hoed ground.

§ With 6 cwt. gun and two gunners mounted (at 13 stone each).

‖ With 6 cwt. gun and five gunners mounted.

¶ With 12 cwt. gun and five gunners mounted.

Or, per horse,

	lbs.	
Horse artillery ...	697·0	actual load,
	618·0	calculated load,
	79·0	difference.
Light field battery,	788·0	actual load,
	724·8	calculated load,
	65·2	difference.
Heavy field battery,	704·6	actual load,
	678·6	calculated load,
	26·0	difference.

The tractive force which each horse has to put forth to move the above actual loads is, as calculated by equation,

	lbs.
Horse artillery	79·14
Light field battery	89·45
Heavy field battery	85·33*

while the force which it is considered each should be called upon to exert, as already given, is

	lbs.
Horse artillery	70·00
Field batteries	82·00

It therefore appears that the gun-teams of horse artillery and light field batteries are considerably overweighted, those of heavy field batteries (of eight horses) not much so; and it is to be remembered that the calculated loads are based upon the supposition that the horses are in fair condition—"reduction of rations, occasional failure of food, and bivouacking often producing great diminution of power."†

Comparing now the light and heavy field battery teams, we find that the heavy battery is more mobile than the light; each horse in the team of the former having to make less exertion than in the team of the latter! In fact, the light field battery, as existing, does not seem, so to speak, an advantageous arrangement; for while the gun carried is but the same as in the case of horse artillery, the gun-team, of six horses, is overweighted, and if increased to eight would be just as much underweighted, and would become more mobile even than horse artillery—which is unnecessary. It would therefore seem better to abolish the light field battery and employ the heavy only, in which each horse is approximately but duly weighted, and yet the team has behind it the heaviest gun; or, if necessary to retain the light field battery, to increase the gun-team to eight horses, and at the same time to increase the weight (*i.e.*, the power also) of the gun carried—

* Allowing, as before, 25 per cent. loss on the leading pair of horses.

† No deduction has been made for any weight on their backs. Against this may be set the assistance which they may get from the momentum of the carriage in motion.

making the gun, total load, and tractive force required per horse a medium, as they should be, between those of horse artillery and heavy field batteries.

On the peace establishment the heavy field battery gun-team consists of but six horses; in which case we have

cwts.	qrs.	lbs.	
50	1	9	actual load,
38	3	3	calculated load,
11	2	6	difference;

and the actual tractive force 106·70 lbs. per horse, instead of 82 lbs., as it should be.

In teams for siege artillery carriages, the pace being the walk, it is usual to employ twelve horses, four abreast.

At the walk, it is considered that a good draught horse can exert a tractive force of 120 lbs.; therefore, deducting 25 per cent. loss for the four leading horses on account of the large number in the team, we have the total tractive force of the latter as $120 \times 12 - 120 = 1320$ lbs. From which, assuming the same average resistance to rolling as in the case of field carriages, or making $\epsilon = 6\frac{1}{2}°$, we find

$$W + W' = 103\tfrac{3}{4} \text{ cwts. approximately, total load.}$$

This gives 969 lbs. load per horse, which Decker lays down for siege artillery should be 750 lbs., and Migout and Bergery 1013·5 lbs.

The actual weight of a 64-pr. M.L.R. siege carriage and limber, packed, is 115 cwts. (about)—no ammunition carried—and of a 40-pr. M.L.R. carriage and limber, packed, $88\frac{1}{2}$ cwts.—18 rounds of ammunition included—which gives for the former a load per horse of 1073 lbs. and tractive force of 132 lbs., and for the latter a load of 826 lbs. and force of 104 lbs.

From this, and considering also that the average resistance to rolling of the ground might fairly for a siege train be taken as greater than for field artillery, it seems reasonable to conclude that the 64-pr. is too heavy a gun to be mounted on a travelling carriage, unless exceptional circumstances render it desirable. If mounted on a standing carriage, the weight of gun, carriage, and platform wagon to transport both (together) would be about 100 cwts., and if mounted on a sliding carriage upon a traversing platform, fitted with transporting arrangement, the weight complete would be about 98 cwts. The latter arrangement could be made suitable for any height of parapet, and would have the further advantage that the gun would be brought into position mounted ready for use—no shifting from one carriage to another, or even changing from one set of trunnion-holes to another, being required.

Wagon versus Limbers.

It is advocated by some that three limbers, drawn by two horses each, might with advantage be substituted for the present ammunition

wagon with six horses—which is set down as a clumsy antiquated affair.*

At first sight, no doubt, such a change appears to have something of advantage in it, as in action the supply of ammunition to the gun, possible to some extent only now, could always be kept up by simply changing the gun-limber for another—though this would hardly seem to meet the views set forth in the "Field Artillery Exercise," where changing the limber to renew the supply of ammunition is laid down as exceptional, the ordinary method enjoined being to shift the ammunition from the full boxes of the wagon or its limber to the empty ones of the gun-limber.

Examining, however, the question in detail, we find the balance of advantage much in favour of the wagon, thus:—

The weight upon the shaft horse, in the wagon 60 lbs., becomes in the limber without a hind carriage 96 lbs., which weight each of three out of six horses, instead of but one, would be oppressed by; the same three horses, instead of but one, having also to bear the constant jerks communicated from the shafts—which, felt to some extent in a limbered wagon, without springs and with fixed shafts, are experienced in the highest degree in a two-wheeled carriage without springs.

Again, with regard to load and motive power, we have the total weight of a wagon (9-pr.) packed equal to 40 cwts. 0 qrs. 2 lbs., while that of three limbers (9-pr.) is 3 (15 cwts. 3 qrs. 4 lbs.) = 47 cwts. 1 qr. 12 lbs., which—the number of rounds of ammunition carried being the same in both cases—gives 7 cwts. 1 qr. 10 lbs. of additional and perfectly useless load. In other words, while in the wagon the load per horse is 747 lbs. and the tractive force required 87 lbs., for each limber these would be respectively 885·5 lbs. and 100 lbs.

Lastly, the number of carriages of a battery would be increased by 12, and the extent of the battery in column of route by 36 yds.†

July, 1876.

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* The wagon can only be said to be out of place when issued to a battery on peace establishment. Would it not be better to place all wagons of horse and field artillery in reserve during peace, and in lieu—from the saving—keep up additional batteries of guns only?

† And query, where would the spare wheels and shafts be carried?

CURRENT FORTIFICATIONAL DEVELOPMENTS

AT THE

GERMAN FORTRESSES OF POSEN AND STRASBURG.

BY

COLONEL H. A. SMYTH, R.A.

Posen, the capital and cathedral city of the region which constituted the ancient Polish dukedom of the same name—astride of the Wartha river, which, though important as an obstacle, is of small account as a means of communication, owing to its shallows, floods, and irregularities—acquires, in these days, with regard to the eastern frontiers of Germany, an importance proportionate with the increasing appreciation of the value of railway communications in war. It covers the intersection of the principal east-and-west railway line of Germany with one of the principal north-and-south lines. Thus those from Hamburg, Bremen, and Cologne, through Berlin, and those from Metz and Strasburg, through Leipzig and Dresden, converge towards it from the west, passing out eastwardly to the frontier fortresses of Thorn and Königsberg, which latter rests on the Baltic; whilst the lines from Stralsund and Stettin, and from Dantzic, on the north, coming together in Posen, pass out southwardly to Breslau (the manufacturing centre of Eastern Germany), thence to Glatz (its most southern fortress), and over the southern frontier to the Adriatic, the Danube, and the Black Sea. So is provision made for rapid concentration of men and means—the kernel of that doctrine of superior mobility which Frederick the Great so well illustrated, and which his successors so essentially recognise.

Its strategic position with regard to the eastern frontier (the whole length of which, from the Baltic on the north to the chain of the Riesen Gebirge on the south, lies naturally open), with Thorn and Königsberg on its left front, and the reconstituted fortress of Glogan on its right rear, gives it a commanding potentiality upon the flank of any operation which might be undertaken against North Germany from the east.

The place was thoroughly fortified by Prussia between the years 1828 and 1854, commencing with detached forts on the more important positions, and concluding with the enceinte which connected them all together; and may be held to have exhibited the latest developments of the Prussian system of fortification up to the commencement of the rifled-arm period. A recognition of the features which the fortress then offered, as well as of those which are now to be added to it, should enable us to arrive at a fair

general conclusion as to what are the points which the Prussians consider most urgent in the present fortificational situation.

The surface of the country about Posen being of that formation which has been termed, in recent geology, quaternary (that is, the sand and gravel deposits above the tertiary), offers but little feature decisively available for the purposes of the military engineer. Its long plains and sandy swellings attain neither to particular limitation nor prominence, except where modelled into some shape by the river and its small affluents. The streams have, indeed, been taken advantage of in the scheme of defence, and prepared to serve as obstacles and for inundation, as far as practicable; and the most considerable knoll declared by the river (having a command of somewhat more than 100 ft. over its valley) was occupied, as the first step necessary for securing the position, by the powerful self-maintenant fort of Viniary; yet there remain fully two-thirds of the circumference of the place innocent of natural qualification for defence, and thus a fair field for the exhibition of the art, pure and simple, of fortification.

The fortress proper, enclosing the city and large military depôts, is of somewhat circular general disposition, with diameters varying between 2000 and 3000 yds. Its main body lies on the western side of the river (which here runs nearly from south to north); that part of it which lies east of the river having much less frontage and depth, and containing but little of importance;* yet the eastern portion of the enceinte is composed of fronts of the same construction as those of the western, and its flanks receive support across the river from the projecting extremities of the latter—especially from that on the north, which constitutes Fort Viniary. These fronts may be supposed to have expressed, at the time of their construction, the protest of the Prussian Engineers against the self-proferent saliencies and angularities of the bastion systems, in recognition of the increasing power of siege artillery. Their trace runs very nearly straight from angle to angle of the polygon (retaining but the merest rudimentary expression of flanks in certain slight undulations of the parapet opposite to the ditches of the ravelin), and the defence of the main ditch is committed to peculiar and mighty caponnières, which cross it perpendicularly in the centre of each front, and which, carrying their two and even three tiers of guns below the level of the superior crests in front of them, are designed to retain the artillery command, in their proper sphere, up to a very advanced period of the attack. These caponnières have their ends towards the country covered by ravelins, which, whilst reaching with their salients about as far forward as those of the modern bastion trace, yet offer less length of face to the action of enfilading batteries, being based on a straight and not a re-entering main line of rampart; and the usual covered way runs round the whole—distinguished, however, by the provision of bomb-proof block-houses, or small casemated barracks, in the salient and re-entering places of arms, covering the heads of the communications, and themselves covered from horizontal fire by the glacis. A casemated work of the same nature, but stronger, is constructed in the gorge of the ravelin, giving close defence to the interior of the latter, as well as additional cover to the head of the caponnière.

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* Unless the cathedral be excepted. It has, however, little architectural merit or antiquarian interest; only its title and the custody of some reputed relics commend it to notice.

The escarp walls are, for the most part, "detached;" only where—as at the angles of the polygon—a plunging power of musketry fire was to be retained, the rampart has been kept close up to the demi-revetment. The counterscarp has a gallery along its whole length, and smaller galleries and caponnières are freely supplied to any corners in need of them. From the counterscarp gallery is carried forward a system of countermines, the details and extent of which are judiciously kept secret, whereby the proper moral effect of such occult defences must come to be enhanced, both in current repute and on occasion of actual trial.

So far the regular Prussian system; what Posen showed peculiarly its own was the extreme development of the caponnière. These works, prolonged inwardly right through the rampart of the enceinte until they flanked its reverse slopes, widened sufficiently to afford roomy open spaces in their interior (large enough, indeed, for the ordinary parades of their garrisons), topped with earthen parapets commanding all the adjacent works, and completed for self-defence by small musketry caponnières in front and by the almost bastion-front tracing of their gorge walls—the rampart being kept separate from them by cuts across it to the depth of the main ditch, and retaining its communication with them only by the continuation of its detached escarp wall and by drawbridges—constituted a sort of chain of detached forts, which were merely connected by the adjusted joints of the enceinte: the latter, though considerably heightened at the angles, for command and against enfilade fire, being kept so narrow as to afford but a very unsatisfactory site for the lodgments of a besieger.

Finally, the strength of the place was enhanced by the advanced fort of Viniary. This work—connected indeed with the enceinte, yet complete in its own system of defence and surrounded by its own glacis, on a commanding site, having its outward face composed of three fronts of the Prussian system (not quite so fully developed as those of the enceinte, being of earlier date), its flanks indented applications of the same principles, and its gorge closed with a casemated keep well capable of accommodating five or six thousand men;—holding, moreover, the control of extensive inundations which would isolate it from the rest of the fortress—was fit to fill the office either of a powerful detached fort against the earlier operations of a besieger, or of a citadel capable of independent defence after the reduction of the rest of the place.

Of the advantages peculiar to the above method at the time of its introduction—which consisted principally in its small subjection to enfilade fire, its force of direct commanding fire from the body of the place, its abundance of bomb-proof cover, and, more especially, its retention of the artillery command of the main ditch up to an advanced period of the regular attack—the last (which needed for its exact evaluation the solution of the then curious artillery question of how far several tiers of guns in casemates might be reducible by one tier in earthern counter-battery on the crest of the glacis—which solution, unmixed, the world is hardly likely to see since the introduction of curved fire from rifled guns—and which, whilst fully effective against attempts of *accelerated* siege, appeared to retain but little validity in the face of advanced operations perseveringly pushed by means of regular mining attack) must be held to have undergone important modification by the influence of the enhanced powers of rifled artillery. The caponnières,

now patent, in their lofty walls, to the accurately curved course of rifled projectiles, may certainly be ruined from a distance; and the same predication applies, under an essential peremptory limitation, to all the masonry escarps of the place—under the condition, that is, of a sufficient amount of means being available. The amount of means sufficient to destroy from a distance a suitable extent of the escarps of this system—taking into account the depth and narrowness of the ditches, the peculiar construction of the detached escarps,* and the solidity and counter-arching of all the revetment walls—would no doubt be large; but the quantity, granted the recent improvements in quality, lies within the province of fair calculation, and may be duly and fully provided.

Yet, however great the degree of intrinsic strength which may be credited to the actual works which enclose the place, its interior has become distinctly liable to bombardment from a distance. Barracks, storehouses, magazines, workshops, and town, within, as well as the very extensive railway plant and stations without,† might be destroyed with certainty and convenience under a given expenditure of time and ammunition, and the place be left a mere self-defensive shell from which the kernel of active force had been burnt out.

Therefore the existing fortress is to be surrounded by a series of eleven detached forts, at distances from the cordon of between 3000 and 5000 yds., and at intervals from one another of between 2000 and 3000 yds. These forts will be supported, according to the necessities resulting from the shape of the ground, by intermediate batteries in retired positions, to the number of five or six. These batteries are to be composed of little more than a massive parapet with a moderate allowance of obstacle, the exact form and armament remaining to be adjusted at the last moment to the developments of the purpose of the enemy. The batteries, in their turn, are to be supported by adjacent covered way, with parapet, which is to be constructed wherever desirable. A circular road will connect all the forts together—running, as directly as may be, just in rear of them; a "girdle" railroad will pass round between this and the body of the place (the existing railroads, where running tangentially to the latter, being largely utilised); radial railroads and roads will run to the individual forts; and telegraph wires will be laid from each of them, underground, to the centre and to its fellows.

It is worthy of note that, whereas the original design for the detached forts had laid them down at distances averaging nearly 5000 yds. from the enceinte, according to which the road of circuit would have measured some 30 miles—the present Governor of the fortress having remonstrated against the occupation of such an extensive line, on account of its necessary aggravation of the task of the general military defence in such matters as the system of outposts, guards, reliefs, communication, and superintendence—the

* It is proper to remember that these escarp walls, having the upper two-thirds of their height detached and only the lower third backed by the earth of the rampart, cannot possibly, when cut down so far by fire, let down any sufficient quantity of earth or *débris* to neutralise the effective obstacle still offered by their remaining solid-revetment bases.

† In these eastern regions of vast plains and cumbrous long trains, the depôts, few and far between, cover a very great extent of ground, and are found necessarily outside the enceinte of regularly fortified places.

scheme was altered to suit his view of the general military situation, by bringing in the more advanced of the forts, where circumstances allowed it, from 1000 to 2000 yds. nearer to the place. Still, the circumference to be held by the defence measures about 20 miles.

All the forts, I was informed, are to exhibit the same general idea, though slightly varying in dimensions—on a trace offering wide front and little depth, sunk low in the ground, parapets and traverses massive, casemate accommodation copious, ditches deep and narrow and defended by low bomb-proof caponnières; so far, all respectful to modern artillery. At the time of my visit they were hardly beyond the paper stage of existence;* but I went over the sites of two of them, where the staves set up to guide the earthworkers indicated a very obtuse-angled lunette, with a command over the country of something over 20 ft., faces 60 or 70 yds. long, ditches distinctly less than 20 yds. wide. The place itself was seen but dimly across the rolling plain from these distant positions, and its supporting connection with them appeared, to the unaccustomed eye, somewhat precarious. They occupied the crests of gentle rising grounds, and in the case of most of the sites these crests or swells, however little marked, commanded, by a few feet at least, the similar swellings and undulating hollows of the neighbouring country for 2000 or 3000 yds.; but one of those which I visited (where the original project had been altered in deference to the above-mentioned remonstrance of the Governor, and the designed fort been brought in much nearer to the place) was itself commanded, albeit to the extent of a few feet only, by the next rising ground of the outer country, from which it was separated by about 2000 yds. of gently sweeping hollow. This instance may perhaps serve as some measure of the degree to which the German authorities will still subordinate the new requirement of the defence—viz., cover from distant bombardment—to its antagonistic but primeval and inherent need —viz., facility for close co-operation of its parts. Yet, even with such abatement, the distances of the positions for the batteries of a besieger, and the difficulty of the objects to be attained by them, appeared to me very serious; and I the more recognised that the artillery of the future, if it be to achieve the stretch of action augured for it, must bring into play unexceptionable optical as well as ballistic powers.

The present garrison of the place consists of seven battalions of infantry, from four to eight batteries of field artillery, some squadrons of cavalry, a battalion of garrison artillery, and another of military transport-train. (This latter, though originally designed as part of the war establishment of an army corps, is now kept up also in peace time, and found admirably useful.) In war time it would be from 20,000 to 25,000 men, and with the occupation of the detached forts, not less than 30,000 men; but under such circumstances it is probable that an army or an army corps would be held ready within the precincts, which would thus become a covered† camp, powerful to affect the strategic relations of the adjacent territories.

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* This was early in April, when winter was only in the act of departing, and snow was still lying in the country ditches. Work was just beginning in earnest, and already, I should suppose, some considerable amount of defensive strength will have been arrived at.

† Or "fortified," or "protected." I have avoided the employment of the hitherto usual term "entrenched," because it appears to me to have become, of late years, fully outgrown by the

The armament is composed of rifled guns for the general defence, and of smooth-bore field pieces (old bronze muzzle-loaders) for most of the flanks—the Germans having satisfied themselves that the fire of the latter is more effective, over a limited range, than that of the mitrailleuse; and this determination of the question must be regarded, at any rate, in so far pure and unbiassed, as that the usual perturbing considerations of economy were in abeyance—the country having in store a superfluity of either weapon. The rifled artillery appears to consist principally of 8-in. howitzers and 6-in. guns—the former of bronze, of the pattern originally termed and treated as mortars, mounted on mechanically-traversing, labour-saving, recoil-checking carriages; the latter, forming the main strength of the armament, of various patterns, lengths, and weights, and variously of iron, steel, or bronze (this being also the order of their power and weight)—the last metal being still considered eligible, on account of convenience of manufacture and economical conversion of the stocks in hand, for the construction of those shorter and lighter guns which, burning but moderate powder-charges, do not demand great strength or resisting power in their material.

One incidental feature of the interior economy generally observed with regard to the armament of German fortresses—viz., the keeping the guns and carriages, not on the works, but dismounted in convenient adjacent storehouses—lends a peculiar value to the artilleristic training involved in the general exercise for the garrison (which comes off every year for several consecutive days) of carrying out the operations of the defence against a given supposititious regular attack. On these occasions, outposts, pickets, and guards are established, the works concerned are manned and armed, embrasures are cut, expense magazines and supplies of all kinds made ready; so the different branches of the service learn not only their own place and work, but also their relation to and dependence on one another, to a degree which is not so generally attainable in the more settled regularity of British garrisons.

Strasburg,* on the river Ill, nearly a mile west from the Rhine, commands the principal natural lines of communication by land and water up and down the Rhine valley, at the points where they are crossed by the main east-and-west road between Southern Germany and France. This road was necessarily determined, from the earliest times, by the best natural track,

increasing size and character of the sort of work to which it was originally applied. The word which was precisely fitted to such defences as a Roman legion in Britain would throw up to secure its halting-place for the night, can hardly be appropriate to a chain of permanent forts, 20 or 30 miles long, resting on a first-class fortress.

* Owing to an accident in the transmission of my application for permission to inspect this fortress, I visited it without that special authorisation from the German Head-Quarter Staff which had procured for me every facility and personal kindness in my pursuit of fortificational information at Posen. I found that without such authority I could obtain no more privilege of observation than the ordinary tourist, who is supposed to be effectively precluded from any close investigations. Nevertheless, working as a tourist, I had no great difficulty in making myself acquainted with all the principal features of the place; and I should suppose that, in the present day, in fortresses of the new and extended system, but few particulars can be reserved from the cognizance of observant military travellers; unless those connected with subterranean defence.

through the defiles of the Black Forest on the east side of the river, and over the passages of the Vosges Mountains on the west side; and Strasburg would appear to have been founded (originally by the Celts, re-established by the Romans, obliterated by the Goths, and, after successive destructions, finally reinstated on the same site by the Franks—fortress and cathedral growing up together, and flourishing in virtue of their reciprocal power, after the manner of the earlier middle ages) not, indeed, at the actual crossing of the road and river, but on the nearest spot of eligible land thereto—the adjacent country having been marshy and subject to flooding, whilst the actual site is sound and slightly raised above the neighbourhood. The original establishment, moreover, having been confined to an island of the Ill, enjoyed the advantage of complete enclosure by an important natural moat. This advantage, as the place has grown, has been converted into a power of very extensive inundation of the adjoining lands.

In the matter of railway communications, Strasburg covers the southernmost intersection of a principal north-and-south line with one of those main east-and-west lines which, passing by or through the central depôts—such as Magdeburg, Leipsig, Dresden, and Berlin—connect the two frontiers together, and allow of the rapid presentation of strength at either extremity. In strategic relation to the frontier, having Metz on its right front, it screens the remainder of South Germany against any operation from the west—much as Posen serves for North Germany towards the east.

The fortifications of the place (strong from the earliest periods; thoroughly re-established by Vauban on a most comprehensive scheme, and endowed by him with facilities for laying the country under water round fully three-fourths of their circuit; added to by succeeding engineers according to the vogue of the times; and reckoned, up to the beginning of the rifled-gun period, unapproachable and impregnable) presented at the time of the last war an encircling belt, of from a quarter to half a mile in depth, of manifold permanent works, in almost labyrinthine profusion of design—with citadel, bastioned enceinte, retrenchments, ditches (wet and dry and variable), counterguards, outworks, and advanced works; the inundation outside all except the western parts: yet, after resisting unshaken the first effort of the besiegers to override its powers of regular opposition by the sudden shock of unforeseen unprecedented bombardment from a distance (an essay which was very successful at some other places at about the same period), the fortress succumbed, in the short space of one month, to the German regular attack—fairly laid open by the immitigable ever-biting action of a persistent scientific fire from heavy rifled artillery.

Now, to protect the place, as a centre of supplies and communications, from distant bombardment; and, moreover, to present to the regular attack defences less liable to rapid disablement than those of the earlier systems; at the same time establishing the seat of a great strategic camp; a ring of detached forts is being planted around it, at an average distance from the cordon of nearly 5000 yds. and from one another of somewhat more than 2000 yds., with a margin of variation of nearly 1000 yds. either way—according as the local circumstances of the ground afford, in the former relation (as to radial distance) sufficiency of command nearer or further from home, and in the latter (as to lateral interval) sites more or less favourable for the operations of a besieger. Thus these works occur much

nearer together on and near the ridge of low hills which faces the place, at nearly three miles distance, from the north-west, which was occupied in the last siege by the earliest works of the besieging army, whence the first shells were thrown into the fortress, and which constitutes almost the only rising ground within bombarding ranges; and much further apart on the low lands adjoining the rivers.

Nine of the detached forts, on the west side of the Rhine, are already completed and armed; three more, on the east side, are under construction; and report says that two more are to be added to these three. They are all on one general plan—though some of them may run a little larger and contain a few more guns than others, where occupying more important sites—and are mainly noticeable for their massive construction, their essential disposition for cover, and their provident accommodation for their armaments. The form is that of a very obtuse-angled lunette, closed at the gorge with a small bastioned front; with a command over the country of apparently about 25 ft., a thickness of parapet of 25 ft., earthen traverses (one running the whole length of the capital and carrying within itself very roomy interior communications, and one to each gun, with internal bomb-proof chamber) nearly as thick, and overtopping the parapets by a good 3 ft.; the gorge works notably lower than those of the front,* and the interior space deeply sunk; the faces and flanks having detached escarps, the tops of which are some 10 or 12 ft. lower than the opposite crests of the glacis, which are raised 6 or 8 ft., at a slope of 45°, from the summits of the counterscarps; the ditches having a width of about 40 ft., and a depth of nearly 30 ft. These latter are defended by three covered musketry caponnières, of which that at the salient, having its sides traced perpendicularly to the faces which they flank, and its front somewhat rounded, assumes a kind of dove-tail or fan shape in plan; while those at the shoulders, having towards the front a mere dead continuation of the escarp wall of the face, are loopholed only on their reverse sides, which defend, and are perpendicular to, the flanks. In each case they are carried across the whole breadth of the ditch, which is nevertheless preserved at its proper width around their ends by sufficiently recessing the counterscarp at the required places: these recesses are provided with loopholed counterscarp galleries, which are of self-defensive trace and complete the defence of the caponnières.

The small bastion front of the gorge defends its own ditch—the more

* It appeared to me, judging roughly by eye, that the gorge crests were, according to the normal design, some 10 or 12 ft. lower than the front crests, with a direct horizontal distance averaging from 80 to 100 ft. This amount of drop would not indeed be sufficient to keep these works below the effective reach of good curved fire; but in many instances, where the slopes of the ground have lent themselves to the situation, the lunette has been planted with its faces just occupying the top of the swell, and its gorge lying a little way down the reverse slope. Thus, constructed on a plane of site inclined to the rear, the fort certainly lies little open to ordinary projectiles arriving from the front; but, it must be observed, by this same construction it is proportionally exposed, in its main rampart and means of action, to any enterprises contrived against it from the rear.

The interior spaces, 12 or 15 ft. lower and 20 or 25 ft. nearer to the front, may be considered pretty well out of all but vertical fire. It is to be observed of them, however, that they have become so circumscribed in extent by the inward slope of the massive earthen banks all round them, as seriously to threaten the maintenance of that freedom of assembly and of movement of troops which has been hitherto generally essential to activity of defence.

powerfully in that its escarp (a regular demi-revetment, counter-arched, and sustaining behind it a regular rampart and parapet) constitutes the face of a double-storied barrack, complete in all respects for 1000 men, in the arrangements of which a well room and a telegraph room are specially noticeable. The communication with the country runs from the centre of this barrack, over the ditch of the gorge by a draw-bridge, on to a small place of arms, which is covered by ordinary glacis, and contains, besides the entrance, a defensible bomb-proof guard-house, and, notably, the main powder-magazine. The earthen covering of this last rises to about the level of the cordon of the opposite gorge-rampart, and offers in that direction some 40 ft. of horizontal thickness.

Expense magazines and shell rooms are within the fort, each adjacent to its own gun—an accommodation fitly bestowed on the choice and comparatively select few pieces composing the armament. From four to five guns for each face, and from three to four for each flank (counting the one gun at the angle of the shoulder in both reckonings), giving from 12 to 16 heavy guns per fort (the armament of the gorge remaining apparently undetermined at the time of my visit)—all 6-in. breech-loaders of the new full-powered pattern—are comfortably housed in store-rooms under the ramparts. I was informed that they were shortly to take up their more permanent residence, each within its own traverse, on the level of its own platform, until brought out on occasion; but this information was by no means official, and I did not quite see that a sufficiency of house room was immediately available for such lodgment.* They are to fire from high carriages, over full uncut parapets. With the high mound of the traverse shielding them on either side, the place of each for action becomes a sort of earthen chamber, open only towards the sky and the rear, of a decidedly serviceable and comfortable appearance.

From the gorges of the forts, generally, covered ways are led, right and left, in the direction of their neighbours—but not continuously so, as they only appear, at present, in the more important situations; and they are, at places one or two hundred yards distant laterally from some of the more exposed or influential forts, developed into sites for powerful batteries, with 50 or 100 running yards of the usual massive earthen parapet, bearing on the general front and the approaches, but awaiting armament and completion until occasion and special object declare themselves. But these inchoate batteries are not far withdrawn from the front of the defence, as at Posen, but are pretty well up with the line of the gorges of the forts, and are only just kept back behind the lines of fire of their flanks.

A circular road, by the backs of the forts, is nearly completed, and radial roads running to, or near to, most of them, are supplied by the already existing roads between town and country. Telegraphic communication underground is provided, but the railway system has not been much moulded to military model. Main lines from the north, the east, and the south-west join a line which makes two-thirds of the circuit of the place,

* Unless the ammunition and stores were removed to a lower story, the chambers of which appeared to be in course of construction immediately under the upper ones. Both tiers of rooms open towards the rear; the interior slope of the rampart having a broad level step (almost a second terreplein) at the level of the lower floor—very convenient for the general communication.

outside the glacis, and passes into it to the one and only station. Here is, no doubt, a certain amount of the framework for a complete system of military railway communication—requiring, however, considerable additions before it can be reckoned fit for regular work. And, as a post of observation and signals, the spire and towers of the cathedral may not be left out of mention: they offer, from a height of 450 ft. downwards, various convenient stations little obnoxious to hostile fire; and it is worthy of note that during the last siege the garrison was able to maintain its employment of them to this purpose until the end.

Remarks.

The particulars of the additional works designed to adapt these two fortresses to the necessities of the present-day defence—actually, for the most part, applied in the case of the older one at Strasburg, and in course of application to the very recent one at Posen—are similar in character; only in degree, there is more provision for the intercommunication and mobility of the defenders, and more distinct shallowness in the trace of the individual forts, *promised* in the later instance. As to the general purpose of these chains of detached forts, though it may remain open to question whether they, in the present instances, absolutely preclude an effective bombardment of the body of the place as long as they remain effective, yet it is evident that as fortified camps they constitute most influential strategic positions; and, moreover, that the body of the place must remain free from serious attack until after their reduction. As to their particular strength, it would seem that the regular attack must find very great difficulty in applying to them the old-established processes of enfilade, counter-battering, or breaching fire, owing to their flatness of trace, massive and lofty traverses and unbroken parapets, narrow ditches and sunk escarps: nor would the more modern expedients of vertical and of curved fire work at their most telling and satisfactory rates, on account of the same limiting conditions: mining would, then, become the most suitable resource, or accessory measure, for the besieger to bring into play; but to this process also—however surely ruinous eventually to the defence, if pushed perseveringly home—some basis of hindrance and opposition is already prepared in the roomy counterscarp galleries and the undeclared extensions therefrom: and as these forts are, moreover, susceptible of intimate support, according to the urgency of the occasion, from their flanks and rear, and remain always open to reinforcement by an active garrison, they appear to offer to the attack a more difficult and uncertain task than did the more continuous but less apposite strength of previous systems.

In the two examples here exhibited, we see, of the new style, simply those additions which have been thought necessary to the present completion of certain fortresses formerly completed according to older styles; but not the whole system of fortification which might be adopted in case of devising a fortress radically, from the very beginning, to meet the requirements of the present day. The relative proportions of the total strength to be put into the detached forts and into the body of the place must vary according to the nature and purpose of the fortress, as well as to the features of the ground. Thus, a small fortress, intended merely to command a certain line

of communication, may be all, or nearly all, body (constructed on the same principles of cover, &c., as the new works above described), with only such detached forts as may be necessitated by neighbouring shapes of the ground; a larger fortress, including a depôt or arsenal, would require, in addition to a regularly fortified body, some detached works to contravene bombardment; a fortress of the largest class, serving to protect a frontier and to secure a strategic camp, might consist almost entirely of a system of detached forts (including, of course, their proper concomitant supporting works), with a body only so far fortified as to be secure against surprise or assault—the amount of extensiveness of the system employed being no more than proportionate to the inherent importance of the place, on account of the great strength of garrison which the active defence of the system of detached forts demands.

But in the two instances before us—the latest expression of the views of the most persistently scientific war-administration of the day—are no doubt evinced some leading principles for fortification under rifled-gun conditions. Additional principles may be yet to be developed, and the complete system not to be arrived at until after progressive trials and vicissitudes; but, in the meantime, the superiority must abide with those who shall detect the principles which underlie contemporary failures and successes, and who will thence be enabled to apply them to immediate practice with only such modifications of detail as the circumstances of the occasion may demand.

London,
June, 1876.

PRÉCIS OF THE FRANCO-GERMAN WAR.

BY

CAPTAIN S. C. PRATT, R.A.

PART II.

METZ TO PARIS. (20TH AUGUST TO 31ST OCTOBER.)

The Army of Chalons.

THE original left wing of the French army, under the command of Marshal Macmahon, which was concentrating since the middle of August at the camp of Chalons, consisted of the 1st, 5th, 7th, and 12th Corps, with the cavalry divisions of Bonnemain and Marguerite. Continuous retreats and defective administration had exercised a most demoralising influence on the *morale* of the troops already engaged, but the newly formed 12th Corps contained an excellent nucleus of well-trained men hitherto unshaken by defeat. A futile endeavour was made to utilise the Parisian Gardes Mobiles, who proved mutinous and unmanageable, and were obliged to be sent back to their homes. At the capital itself two more corps (the 13th and 14th) were in process of formation, though they were not organised in sufficient time to take the field. Exclusive of these last mentioned troops, the Army of Chalons had an effective on the 20th inst. of 120,000 men with 324 guns.*

The position of the French General was undoubtedly a difficult one; on the one hand it was his object to cover the capital, on the other to assist Bazaine and enable him to break through the formidable circle of investment that surrounded him. To risk the defeat of his troops by offering battle at Chalons would be dangerous, and but temporally check the German advance; to retreat on Paris would undoubtedly lead to the fall of the Napoleonic dynasty, the prestige of which was already severely shaken. The exigencies of the political situation demanded an attempt to succour Bazaine, while purely military grounds dictated the necessity of a retirement to the capital. The plan of campaign suggested by the War Ministry was to advance in three main columns through the Argonnes towards Verdun, and thus gain the valley of the Meuse. Such an operation could only be effected

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* On the 25th, 408 guns and 84 mitrailleuses, the total number of combatants being slightly increased.

by making a flank march between the III. German Army and the Belgian frontier, and incurring the risk of a simultaneous attack on front and flank. Taking the most favourable view, it might possibly lead to the corps of the Meuse Army being beaten in detail, and as a probable consequence enforce the raising of the Metz investment. The hazardous nature of such a movement, combined with the fact that in case of Bazaine breaking out southwards it would be perfectly futile, was fully apparent. The absence of authentic information as to the exact position in which the army of the Rhine was placed increased the difficulties of the situation, and Macmahon, to temporally escape his dilemma, determined on the medium course of marching on Rheims, to take up a position which would enable him to await the development of the enemy's plans, and at the same time flank the direct approaches on Paris.

On the 21st the march northward was commenced, the camp being evacuated in such haste that large stores of food, forage, and clothing had to be burnt. On the morning of the 22nd a telegram from Bazaine, stating that he believed he could continue his retreat in a north-westerly direction through Montmèdy, was received, and led to the cancelling of previously issued orders for retirement towards Paris.* Influenced by this despatch, and fortified by the unanimous opinion of the War Ministry, the Marshal started in column of corps on the morning of the 23rd in a north-easterly direction towards Dun and Stenay,† having previously warned Bazaine of his movement.‡ In consequence of the difficulties experienced in feeding the troops, it was found necessary to approach the line of railway, and the whole of the 25th was occupied in rationing the army in their bivouacs at Vouziers-Rethel. 21st Aug. 25th Aug.

Whilst the I. and II. German Armies were taking part in the decisive struggles before Metz, the III. Army was advancing slowly westward on the capital. Its main body had crossed the Meuse on the 20th of August, the three leading corps having reached the line of the Ornain. To co-operate with these troops, three army corps were—as before mentioned—detached from the forces investing Bazaine, and formed what was called the Army of the Meuse, under the command of the Crown Prince of Saxony. The III. Army was obliged temporally to halt, to allow this new body—which started from the Gravelotte plateau on the 19th—to come up into line. The entire German force destined for the advance on Paris was eventually, on the evening of the 22nd, in a line facing west extending from Etain to Gondrecourt (50 miles); the Meuse Army forming the right wing, and the cavalry on the left being pushed

Advance of III. and Meuse Armies. Part I.

* This despatch was dated 19th August, and written the morning after the battle of Gravelotte. It appears there was also a second telegram, couched in somewhat less hopeful language, dated the 20th August, which Macmahon declares he did not receive. As a duplicate of this second message (which Col. Stoffel was accused of intercepting), did not strike the Parisian War Ministry as containing any additional information, it is difficult to conceive why so much importance has been attached to it. (*Vide* "Procès Bazaine." "La depêche du Vingt Août," par Stoffel.)

† The direct route through Verdun being already intercepted.

‡ A duplicate of this despatch reached Metz on the 30th August, and led to the sortie towards Noisseville the following day.

forward as far as the Marne Valley.* Aware that the French forces were in the vicinity of Chalons, the advance was continued on a broad front in a westerly direction. On the 24th the general line of Verdun-St. Dizier was reached; on the 25th that of Dombasle-Vitry, the cavalry of the right wing being pushed through the Argonnes to St. Menehould.

25th Aug. Map V.

Reviewing for the moment the position at this date, it will be seen that a French army of more than 100,000 men was moving *eastward* towards Montmèdy, while the Prussian forces, two days' march to the south and unaware of the circumstance, were marching *westward* towards Paris. The first information the Germans received of the evacuation of the Chalons camp arrived late on the night of the 24th, in the form of a telegram, which stated that Macmahon had taken up a position at Rheims, and was about to *relieve Bazaine*. As the direct road to Metz was barred by the Meuse army, it was obvious that the only means of carrying out such a plan would entail a hazardous flank march in close proximity to the Belgian frontier. As this seemed a somewhat improbable course, the German leaders contented themselves with directing their general line of advance in a north-westerly direction towards Rheims.

MacMahon, on the other hand, was on the 21st undoubtedly aware of the existence, numbers, and general situation of both the German armies. His flank march was made with a full knowledge of the danger incurred, and it was easily apparent that its only chance of success lay in extreme rapidity of execution. The delays at Rheims and Rethel had already imperilled the movement, and the further causes that led to the disaster of Sedan can be best traced by following the movements of both armies for the next few days.

26th Aug. On the 26th, the French army wheeled leisurely to the right on the pivot of Vouziers, for the purpose of advancing in two main columns on the Beaumont and Buzancy roads. In the afternoon, the cavalry of the right column (7th Corps, under Douay) reported the presence of hostile troops at Grand Pré, and this corps, in consequence, formed up in battle order, somewhat unnecessarily, at Vouziers.

Owing to information received late on the 25th as to the movements of Macmahon, provisional orders were issued to both German armies, depending on the reports to be brought in by reconnoitring cavalry. As a result, the Meuse Army, changing its front, moved northward in anticipation, and with its leading troops reached Varennes. The III. Army closed in their corps to their right flank, so as to be ready either to advance towards Rheims or follow the movement of the Saxon Crown Prince. Covering these changes of direction, the cavalry ex-

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	Infantry.	Cavalry.	Guns.
* III. Army	118,095	19,567	525
Meuse or IV. Army	70,028	16,247	288
Total	188,123	35,814	813

III. Army.—V., VI., XI., I. Bavarian, II. Bavarian Corps, Wurtemburg Division, and 2nd and 4th Cavalry Divisions.

Meuse Army.—Guard, IV., XII. Corps, and 5th and 6th Cavalry Divisions.

tended in an arc from Dun to Chalons; their persistence and daring forming a strong contrast with the inaction of their opponents.

Apprehensive of an attack from the south, Macmahon moved three of his corps into the line Vouziers-Buzancy; but as no attack was made, counter-orders were issued for the resumption of the march in a north-easterly direction. Resulting from these conflicting movements, but little ground was gained on this day. 27th Aug.

From the reports of the German cavalry, the presence of hostile troops of all arms at Vouziers and Buzancy was clearly established, and the orders for a march northward accordingly confirmed. The Meuse Army seized with its leading corps the river passages at Dun and Stenay, while the III. Army, a long day's march in rear, reached with its advanced troops the line Clermont-St. Menehould.

In view of the threatening advance of the enemy, a retreat northward was determined on, and the relief of Bazaine abandoned. Unfortunately, the persistence of the War Ministry again constrained Macmahon to a course opposed to his military judgment, and counter-orders were issued for a continued advance eastward. The objective of Montmèdy was clearly pointed out to the corps commanders, and the necessity of seizing the bridges over the Meuse at Stenay and Mouzon insisted upon. These constantly changing instructions led naturally to much discomfort and confusion; the roads were encumbered with baggage and provision columns in inextricable disorder, and but short marches were made. At nightfall the 5th Corps reached Bois-des-Dames (south of Beaumont) on the southern road, the XII. Corps the neighbourhood of Stonne on the northern, the two corps in rear gaining the line of the Bar. 28th Aug.

The IV. Army meanwhile moved up its rearmost corps along the left bank of the Meuse, still holding the river passages with its advanced troops, while the III. Army steadily advanced up the valley of the Aisne.

On the evening of the 28th information was received that Stenay was occupied in force by Saxon troops, and the bridge blown up. As the army of Chalons had no pontoon train, it was decided to retire northward, making use of the bridges at Mouzon and Remilly and eventually gaining Metz through Carignan.

The troops on the northern road were unmolested, but the 7th Corps, harassed in rear by cavalry and impeded by bad roads, only succeeded in reaching Oches—half its destined march. The 5th Corps (owing to the capture of the officer carrying the order for retreat) continued its march on Stenay, was attacked by the Saxons at Nouart, and retired fighting, eventually reaching Beaumont much disorganised by its night march. 29th Aug.

On the German side there was a general tendency for the Meuse Army to halt till the III. Army came up into the line Grand Pré-Dun, the French movements being watched by cavalry. The XII. Corps was, however, pushed somewhat forward, and brought on the action above alluded to. Both German armies completed their deployment in the evening, and between the Meuse and the Argonnes six corps stood ready for advance northward—a general forward movement towards Beaumont being projected for the following day.

30th Aug. To effect the passage of the Meuse at all risks with the greatest promptitude was the burden of the French instructions. In spite of the efforts of the staff, the troops on the northern road, though unmolested, did not succeed in crossing at Remilly till late at night.* The columns on the southern road were still more unfortunate, and had to pay the inevitable penalty of mismanagement. The 5th Corps, owing to the fatiguing countermarches of the last few days, and the demoralising effect of the night retreat it had just concluded, was very tardy in its movements, and shortly after noon was brusquely awakened from a fancied security by vigorous shell fire. It appears that De Failly, its commander, was under the impression that the German forces were marching towards Stenay, and that his retirement would be uninterrupted. As a fact, the whole German armies were advancing down the Meuse, expecting to find Macmahon in a defensive position; and it was some of the batteries of the Meuse Army that spread such consternation through the bivouacs at Beaumont. The advance of the XII. and I. Bavarian Corps into line rendered a retreat through the village compulsory, and the position taken up north of Beaumont had to be relinquished with heavy loss. Pressed in front and flank by superior numbers, De Failly retreated fighting on Mouzon—a movement much facilitated by the woody and intersected nature of the ground. Eventually the river was crossed, under the protection of a portion of the 12th Corps, after severe losses had been sustained.

Engagement of Beaumont.

The 7th Corps, harassed in rear by cavalry, left its camping ground at Oches at 9 a.m., and marched by two roads to the river. The rear of its leading division, mistaking its way, approached close to Beaumont, and was utterly routed by the advancing troops of the I. Bavarians. The main body of the corps, after a tiresome march, crossed the river late at night at Remilly. Under the influence of the defeats sustained by his rearmost troops, Macmahon gave orders for an immediate retreat on Sedan, for the purpose of procuring them food, ammunition, and rest. Throughout the night troops of all arms, intermingled pell-mell, strove each man for himself to reach the required destination, and early the next morning the greater portion of the French army was bivouacked in an exhausted condition around the fortress.

The two German armies, in a concentrated mass on the left bank of the Meuse, occupied meanwhile with their leading troops the line of Mouzon-Raucourt.

31st Aug. The French fugitives came pouring into Sedan from both banks of the river during the early morning. The 12th Corps, which was somewhat in rear, did not arrive at Bazeilles till 9 a.m., when it was fired on from the opposite bank of the Meuse. A brisk contest with some Bavarian troops was carried on, finally resulting in the railway bridge being left intact in the enemy's hands. The 1st Corps, which had acted as rear guard, made from mistaken orders a circuitous march, and did not reach its camping ground till late at night.

It was apparently intended to give the troops rest during this day, as no arrangements were made or orders given for further movement.

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* The 1st Corps—the 12th having crossed at Mouzon the previous day.

Several courses were open now to the French commander—either to break out towards Carignan and Metz, retire on to Belgian soil, retreat towards Mezières, or fight in the positions already taken up. Of these undoubtedly the retreat westward was most in favour, and it was considered that plenty of time was still available for its execution.

The 13th Corps, which had been forwarded from Paris under the command of General Vinoy, was assembling at this time at Mezières.

The German armies continued their march northward, detaching two corps (XII. and Guard) to the right bank of the Meuse, in order to bar the space between that river and the frontier. On the evening of the 31st the contending forces were facing one another with their advanced troops in immediate contact. The boldly conceived flank march of Macmahon had, owing to defective organisation, utterly failed, and his army now stood assembled in a curve round the small fortress of Sedan. Pressing it back against the neutral Belgian frontier, advanced the numerically superior German forces, deployed on a broad front.

The position taken up by the French was tactically a strong one, and well calculated to ensure a stubborn defence. Its eastern boundary was formed by the valley of the Givonne, from the western heights of which effective fire could be maintained over any direct approach. Continuous ranges of hills formed parallel lines of defence to the north-west, and the south and west were protected by the broad valley of the Meuse. The fortress of Sedan, commanded by the higher ground on the opposite side of the river, was but of little defensive value. Two corps overlooked the Givonne valley facing east, one corps (the 7th), faced north-west on the Illy plateau, the remaining 5th Corps, under De Failly, forming the reserve. In order to advance against the position from the west, a detour had to be made round the bend of the Meuse, through a single road presenting the characteristics of a defile. The country lying to the north was hilly and intersected, but towards the east was practicable for large bodies of troops. 1st Sept.

In accordance with orders, the German forces moved forward to the attack during the early morning of the 1st September. Three army corps moved from the eastward against the Givonne position, while two crossed the Meuse at Donchery and advanced towards the Sedan-Mezières road. South of the fortress, on the opposite side of the river, one corps kept guard.* Map VI.

It will thus be evident that two distinct attacks were to take place—one on each flank of the French lines. No special orders appear to have been issued for this day by Macmahon, it being intended to give a rest to the troops, and eventually lead them either to Carignan or Mezières, according to force of circumstances.

The engagement commenced at an early hour in the morning by an attack of the I. Bavarian Corps on Bazeilles—the village, occupied by the Battle of Sedan.

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* Towards Givonne Valley.—Guard, XII., and I. Bavarian.
Towards Sedan-Mezières Road.—V. and XI. Corps.
Watching southern exit.—II. Bavarian.
In reserve.—IV. Corps, Wurtemburg Division, and four cavalry divisions.

The VI. Corps and 6th Cavalry Division remained in rear near Vouziers, covering the left flank.

French right, which was shelled the previous evening. After six hours desperate fighting the town was captured, and accruing reinforcements led to the French being forced back to the heights south of Fond-de-Givonne. Between Bazeilles and Daigny the XII. Corps (Saxons) entered into line, while further north the Prussian Guard captured the village of Givonne. By noon the whole of the Givonne Valley was in German hands, the French holding the general line of the western crest. This loss of ground was mainly attributable to unfortunate changes in the supreme direction. Marshal Macmahon, wounded in the early morning, handed over the command to General Ducrot, who at once issued orders for a withdrawal westward, with a view to immediate retreat on Mezières. General Wimpfen, a senior officer, considering the retreat impracticable, countermanded the movement whilst in process of execution, and endeavoured to re-occupy the valley, in order to make an offensive sortie towards Carignan.

Eastern attack.

Western attack.

On the western side, the V. and XI. Corps crossed the Meuse at Donchery and advanced through Vrigne-au-Bois, skirting the bend made by the Meuse.

The artillery of both *corps d'armée* came into action on the hills north of Floing, and cannonaded the position held by the 7th Corps under Douay. As the infantry came up, they deployed along the heights and pressed forward strongly, especially against the French left at Floing. This village was carried, after hard fighting, and a general advance made against the French line. The cavalry of Marguerite's Division sacrificed themselves in a vain attempt to turn the fortune of the day, and the troops of Douay gave way in all directions. On the eastern side the French were also losing ground, and the German right and left wing pushed forward north till they came in contact.

On the south side of the fortress, the batteries on the opposite bank of the Meuse were during the battle firing at long ranges on the reserves and large fugitive bodies.

By 3 o'clock the circle of investment was complete; and overwhelmed by the fire of nearly 500 guns, the French retreated in confusion to the nearest cover. A bold sortie towards Bazeilles was attempted, but with little success, and by 4 o'clock all the main positions had been abandoned. To show the futility of further resistance, the guns of the victorious army were turned on the mass of fugitives inside the fortress, and about 5 o'clock the white flag of surrender was hoisted on the Citadel.

Negotiations were carried on with a view to capitulation during the night, and the terms finally arranged by 11 a.m. the following day, by which the French Emperor and 83,000 men became prisoners of war.*

The ten days' campaign against the Army of Chalons forms one of the most striking episodes of the war of invasion. The plan projected in

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* In the Battle ...	Killed	3,000
	Wounded	14,000
	Prisoners	21,000
Prisoners at capitulation		83,000
Disarmed in Belgium		3,000
	Total	124,000

Paris for the relief of Bazaine was undoubtedly bold in its conception, though difficult to defend on strategical grounds. To successfully evade the blow of the advancing German armies by a flank march, two conditions were necessary—sufficient time to gain a fair start, and ample space to carry out the movement in. When the advance was made from Chalons, the most northern German corps was in the vicinity of Verdun, and a march had to be effected through the narrow band of territory extending between that fortress and the neutral Belgian frontier. Assuming the greatest expedition to have been used, it would have been impossible, under ordinary circumstances, to escape the notice of the cavalry of the Meuse Army, and contact between the contending forces would have taken place, in any case, more to the eastward in the vicinity of Montmèdy, Etain, or Thionville. If an extensive territory had existed to the northward, it might have been possible to make a long detour and successfully avoid observation; but the limited zone for manœuvring forbade the hope of any such advantage. To gain the requisite time on the enemy, it was necessary to draw him further away from Metz, either towards Paris or the south, or by a feint deceive him temporally as to the projected movement. As it happened, the German armies were in a central position, and were enabled to take advantage of the lesser space they had to traverse on the interior lines they occupied. In addition to the strategical difficulties of the situation, the Army of Chalons was not in that thoroughly prepared state to make it equal to the requirements demanded of it. In spite of these unfavourable circumstances, a partial success was at one time by no means impossible. On the 25th August the French army of over 100,000 men was on the flank of the German advance, and might, if expedition had been used, have beaten in detail the northern corps of the Meuse Army. Whether Metz could have been reached is a matter of opinion, but undoubtedly a well-timed sortie from Bazaine would have given an impulse towards success. To an army incapable from its nature of rapid manœuvring, the safest movement was assuredly towards the fortified capital, where a prolonged stand might be counted on and an investment rendered nearly impossible. As, however, in the political situation this course was impolitic, it would seem that a retreat to the north-west through Rheims, drawing the German armies after it, would have been advisable. If a forward movement towards Metz was a necessity, it would have been safer to make a detour southward and endeavour to conceal the manœuvre by a feint towards the northern Argonnes. Paris might have been left to defend itself (as it was afterwards compelled to do) with the nucleus of regular troops it possessed, and the further advance of the German forces been endangered by the position of a powerful field army on their flank. The deplorable slowness of the marching, and the insufficient scouting of the cavalry, that led to the surprises at Nouart and Beaumont have already been alluded to, and combined with the want of unanimity in direction, formed a series of secondary faults that conduced in no small measure to the disastrous capitulation.

The unfortunate delay at Sedan on the 31st is not easy to understand. The retreat on Mezières would have been practicable on the following day, according to Macmahon's opinion; but it is inexplicable that (as a

precautionary measure) more care was not taken in destroying the permanent bridges over the Meuse and scouting along the flank of the projected movement with cavalry. The successive changes in the supreme direction during the engagement undoubtedly influenced its result; but, at the same time, the order of battle was in itself defective, as it did not cover the line of retreat.

It has been maintained that the German strategy was over cautious, and that a portion of their forces might have been, after the 25th of August, detached towards Paris. It is difficult, however, to see what advantage could have been gained. The French capital was too strongly fortified to have been taken by storm, and the great advantage of numerical superiority over the sole French army in the field would have been thrown away. With a portion of the Imperial army closely invested at Metz, and the remainder compelled to capitulate, no further obstacle opposed itself to an advance on Paris. Within an hour after the capitulation was signed, orders were issued for the march westward, the I. Bavarian and XI. Corps being left behind in charge of the prisoners, for the conveyance of whom to Pont-à-Mousson and Etain arrangements were at once made. At these two places they were transferred to the charge of the troops investing Metz, and by them despatched for internment in Germany.

March on Paris.

The first measure to be effected was the opening out of the two armies from their closely concentrated position round Sedan. The order of march had been somewhat inverted, the lines of communication of several corps having crossed, and this inconvenient displacement had to be rectified. The III. Army started in a south-westerly direction to gain its former position on the left flank, while the Saxon Crown Prince with slower marches advanced westward. By regulating the length of the stages the different corps regained their respective positions in line, and on the 15th the whole force, preceded by four cavalry divisions, occupied a line 30 miles to the east of Paris, extending on both banks of the Marne from Villers-Cotterets to Rozoy-en-Brie.

15th Sept.

As a result of the catastrophe of Sedan, the French empire was overturned by a bloodless revolution on the 4th September, and a Provisional Government formed for the national defence, under the presidency of General Trochu.

Investment of Paris.

Surrounded on two sides by a complex water-line, and on the remaining circumference by a double rampart of hills, the natural defensive power of the capital was undoubtedly great. Exclusive of the inner bastioned line, the city was surrounded by a girdle of 16 detached forts of powerful type, which, however, possessed the disadvantage of being situated on the *inner* range of hills, too near the enceinte to fulfil modern requirements. Energetic measures had been taken, immediately after the outbreak of war, to complete the armament of the forts, and increase their power by the addition of naval guns of large calibre. Several outworks were designed for the outer range of hills, but as they were not finished in time for occupation these matchless positions had to be abandoned to the enemy.

The troops available for defence were the 13th and 14th Corps*

* The 13th Corps had retreated from Mezières after the battle of Sedan. The 14th Corps was composed of regiments hastily summoned from the provinces, gendarmes, foresters, &c.

(about 70,000 men), destined in general for offensive enterprise. Behind these, in second line, to guard the forts and outworks, were a division of marines, 14,000 strong, and the "Gardes Mobiles"—a semi-disciplined force of about 100,000 men. For manning the enceinte and maintaining order in the city, recourse was had to the "National Guard"—an undisciplined mass of doubtful value, but amounting to 300,000 men. The armament consisted of about 3,000 guns of various types, of which 500 could be employed for field service.

Orders for the investment were issued from the German head-quarters on the 15th of September. The Meuse Army was directed to occupy with its three corps* the northern side, in a line extending from the right bank of the Marne to the right bank of the Seine—an operation successfully completed on the 19th inst. The III. Army completed the 19th Sept.
investment on the southern side the same evening, in spite of a vigorous attack made by General Ducrot near Chatillon. The two armies were preceded by three cavalry divisions,† who rapidly seized all the main approaches and forestalled the work of their slower-marching comrades. Owing to the impossibility of filling up the casualties which had so recently occurred, the German corps were much under strength, and their entire force did not amount to more than 147,000 men with 622 guns. With such a comparatively small effective the operation was undoubtedly hazardous, and it is difficult to understand why more resistance was not made to it. The troops which attacked under Ducrot did not amount to more than 28,000 men. Allowing that a large portion of the defending force was not available for field operations, this seems but a meagre per-centage to be drawn from a body of 500,000 armed men, and Trochu himself admits that a larger number might have been employed.

When once invested, the question remained as to the manner in which the reduction had to be carried out. To trust to the gradual effects of a blockade and allow hunger to do its work, attack in a regular manner one of the sides, destroy the forts by artillery, or bombard the town, were measures open to discussion. The decision rested mainly on two points—the means of resistance possessed by the besieged, and the weapons of offence procurable by the investing troops. It was assumed that the defending force would naturally increase daily in efficiency, and eventually be available for powerful offensive sorties. No certain data could be arrived at with regard to the supply of food, but the best informed estimated that with the most rigid economy provisions might last for 10 weeks. As regards the investing force, it was evident that more troops were necessary to maintain a strict blockade; the corps would have to be filled up to their full strength, and the immediate presence of the I. Bavarian and XI. Corps from Sedan was most desirable. Before commencing an attack, whether by artillery or otherwise, it would be necessary to procure a siege train, which would have to be forwarded from the Rhine. This, however, could not be effected till after the cap-

* IV., XII., and Guard.

† The remaining cavalry division was detached towards the Loire, to report on the levies in process of being raised there.

ture of Toul—a small fortress which effectually barred the only otherwise available line of rail. Additional difficulties were interposed by the blowing in of the tunnels near Paris, which would necessitate for a lengthened period the transport of *matériel* in country carts. Pending the restoration of the line, great difficulty would be experienced in feeding the investing troops, and the armies would have to live for a time, as it were, from hand to mouth, till reserve magazines were established. Resulting from these considerations, a resolution was formed to continue an effective blockade as long as possible, and proceed finally, if necessary, to an attack by force. If the latter measure could not be dispensed with, it was decided that the effort should be directed against the portion of the south front defended by the forts of Issy and Vanves. Bombarding the city could only have a partial effect, and would entail an enormous expenditure of *matériel*, besides arousing a feeling of indignation throughout Europe. Measures were accordingly taken to fortify the investing circle. Gun-pits, shelter-trenches, block-houses, and all kinds of obstacles were speedily constructed; villages, walls, and isolated houses put in a state of defence; good communications opened up in rear of the whole line; and ample bomb-proof cover provided for the outposts. Observatories were also constructed at suitable points, and connected by telegraph wires with the several head-quarters. In case of an attempt at relief from the provinces, it was arranged that as few as possible troops should be left on the investing line, and a powerful body forwarded one or two days' march to meet the enemy. On the 22nd September the blockading force was increased by the arrival of its two corps from Sedan, and later on by the 17th and Guard Landwehr* Divisions.

The first sortie on a large scale was made on the 30th towards Chevilly and Choisy, after a heavy preliminary fire from the neighbouring forts of Montrouge, Ivry, and Charenton, but was defeated with heavy loss.

A series of petty skirmishes took place afterwards, during the first days in October. Three weeks had now elapsed since the commencement of the investment, and the offensive and defensive earthworks of the belligerents increased in strength. Great efforts were made throughout the provinces to raise armies for the relief of the city—measures the success of which depended on the prolonged continuance of the state of siege. On the morning of the 13th of October another sortie in force was made against the Clamart and Chatillon heights, resulting in a temporary success. The advance of the German supports, however, changed the aspect of affairs, and the French battalions were driven back in disorder, after some severe village fighting. On the 21st an ineffective reconnaissance was made under cover of the fort of Valerien, which, if conducted by more men and ushered in by less cannonading, might have resulted in a brilliant success. On the 28th, the village of Le Bourget, occupied by a company of the Prussian Guard, was carried by very superior forces, and strongly fortified. On the 30th, after a heavy artillery fire, it was stormed by the Germans, and after some desperate hand to hand fighting the French fell back in great

Re-capture of Le Bourget, 30 Oct.

* Set free by the fall of Strassburg on the 27th September.

disorder. The repulse on this day produced a great moral effect on the city, from the fact that many of its inhabitants were personally engaged, and no sorties were attempted for a long time afterwards.

In considering the operations round the city up to this date (the end of October), it will be noticed that all the sorties were made by comparatively small forces, never exceeding 30,000 men. The several combats were always preceded by a cannonade from the forts in the vicinity of the points of exit—a mode of operation which seems inadvisable, as it at once put the enemy on his guard. On the German side, the difficulty of provisioning the troops was lessened on the 23rd September by the fall of Toul, which enabled a line of rail from Germany to be opened to within a few miles of Paris, and siege equipment to be rapidly forwarded. On the 27th the fall of Strassburg released its investing force, and at the end of October the capture of Metz rendered available the bulk of the I. and II. Armies. The investing force at the end of the month amounted to about 236,000 men with 900 guns, a portion of whom were occupied in the protection of the blockade from the newly raised levies of the provinces—an aspect of the campaign which will be alluded to further on. (*Vide* Part III.)

Turning to the eastern theatre of war, it will be remembered that after the battle of Wörth the Baden Division was detached to the south, to observe the important fortress of Strassburg. At the time of investment the garrison consisted of about 17,000 men, of whom 9,000 were regular troops—principally refugees from Wörth. The fortifications were chiefly of ancient date, there were no detached works, and bomb-proof cover was very deficient. The chief strength of the fortress lay in its inundations, which made an attack impossible except on the north-west front. No opposition was made to the investment, and but two sorties of slight importance attempted. A heavy fire of field guns was at first directed against the Citadel and outworks, and effected some damage among the civil population, in retaliation for which a good deal of injury was inflicted on the open town of Kehl by the French. On the 19th of August the siege park* began to arrive, and the blockading troops were reinforced by the Guard Landwehr and 1st Reserve Divisions. On the 24th a bombardment of the town commenced, and after lasting three days was put a stop to on sentimental grounds. Recourse was now had to the regular siege operations, and a first parallel was opened on the night of the 29th. The attack was pushed forward with vigour, encountering but a feeble resistance, and the descent of the main ditch was commenced on the night of the 26th September. The garrison was not in a position to stand an assault, and the place surrendered on the 27th, the garrison (17,000 men) becoming prisoners of war, and a very considerable *matériel* falling into the hands of the victors. A small garrison from the investing force was left in the town, the Guard Landwehr Division was forwarded to Paris, and the remainder of the troops formed into a new corps (XIV.), destined for operations further south.

Investment of Strassburg, 13th August.

Fall of Strassburg, 27th Sept.

It will now be necessary to return to the consideration of the invest-

Investment of Metz, 20th Aug.

* 200 rifled guns, 88 mortars, and 50 wall pieces.

Part I. ment of Metz. It will be remembered that on the evening of the 18th August (the day of the battle of Gravelotte) the 6th Corps, under Canrobert, which occupied the right of the French defensive position at St. Privat, was defeated, and retired in disorder. Orders were issued at nightfall and carried out early the following morning for a general retirement of the whole French army to the vicinity of the detached forts. The 2nd and 3rd Corps occupied the ground on the right bank of the river, facing south and east; the 4th and 6th Corps, with the Guard in reserve, took post on the left bank, facing the west and north. Strong lines of entrenchment were thrown up connecting the several forts, and the villages in their immediate vicinity placed in a state of defence and occupied by outposts. On the 22nd all losses sustained in the previous battles had been made good, and the troops provided with their full complement of ammunition and warlike stores. The precaution of amassing large quantities of provisions in the city had not been taken till too late, and the supply of food was insufficient for the requirements of a large army in addition to the civil population and the many refugees that had been incautiously admitted into the town. The period for which the rations would suffice depended entirely on the action taken by the field army, and the possibility of its procuring food by sorties.

Map 7. The German corps bivouacked in the positions they had attained on the eve of Gravelotte, and pushed forward the next day to an average distance of two miles in front of the detached forts. The line of investment was strengthened by field works; têtes-du-pont were formed above and below the city, and two principal magazines of supply created at Remilly and Pont-à-Mousson. Deducting the troops of the newly formed Meuse Army, there were available for the blockade the entire I. Army (I., VII., and VIII. Corps), four corps of the II. Army (II., III., IV., and X. Corps), and one reserve division. The ulterior object of Bazaine being a march westward, the main bulk of the forces were kept on the left bank, the right being guarded only by the I. Corps and Kummer's Reserve Division. The following general principles were laid down for the guidance of the German generals:—Sorties to the north and south were to be opposed in front by the corps holding the bridges, and attacked in flank by all available troops. Any attempt westward was to be resisted energetically by all the troops on the left bank, while a troueé in mass to the east, if pushed vigorously, might be allowed to succeed.

Bazaine, on the 18th, had announced by telegram to the Emperor his intention of re-continuing his march westward by the more northerly routes of Briéy or Thionville, and received three days later a despatch from Macmahon stating that the latter was coming to his assistance. He determined accordingly to facilitate the march of the Army of Chalons by drawing the bulk of the German forces to the right bank of the river. If the projected sortie eastward was favourable, he would be enabled to profit by it by taking ground towards Thionville. With this view, the greater portion of the French forces were passed to the right bank of the Moselle on the 26th, and formed up between the forts of St. Julien and Queuleu. Owing to the insufficient bridging of the river, the encumberment of the roads with baggage, and the heavy rains,

the operation was not completed till the afternoon. A council of war then decided not to continue the movement, and the troops were ordered back to their former cantonments. After the reception of another despatch from Macmahon, stating that he was marching towards Montmèdy and would be on the Meuse on the 27th, it was decided that the projected sortie of the 26th should be again attempted on the 31st of August.

Battle of Noisseville: Fr. 120,000 Gr. 74,000

Owing to the usual defective staff arrangements, the march of the troops was unnecessarily delayed, and it was not till 4 o'clock p.m. that the order for advancing to the attack was given. The 3rd, 4th, and 6th Corps were in front line, the 2nd Corps and Guard being in reserve. The main object of Bazaine was to get possession of the Plateau of St. Barbe, which commanded the surrounding country, and would, if held, protect the right flank of his further advance towards Thionville. To guard the line of investment on the east bank of the river were the I. German Army Corps, one reserve division, and one brigade of the VII. Corps, amounting in all to about 45,000 men—less than half the strength of the attacking troops. During the afternoon, the Germans were further reinforced by the detachment of one division of the IX. Corps to the right bank of the river at Antilly. The battle was commenced by a vigorous cannonade, under the support of which the 3rd Corps successively gained possession of the villages of Noisseville and Montoy. With the assistance of the 4th Corps on their left, Servigny was taken at nightfall after a gallant resistance, the French left gaining ground as far as Chieulles and Vany. The French had thus succeeded in gaining possession of the outer investing line, but the movement was not followed up by the advance of the reserves, and Servigny was, about 10 o'clock, recaptured by a night attack.

Map 7.

1st Sept.

Early on the 1st September the German forces, strengthened by the remainder of the IX. Corps, and supported by the closing in to the left bank of the river of the III. and X. Corps, proceeded to retake their lost positions. A severe engagement, attended with varying success, was initiated against the French left, while their right flank was pushed back with vigour. The main losses were incurred, however, in the centre, in the endeavour to regain Noisseville, the capture of which village at 11.30 o'clock led to a general retreat within the detached forts. It appears tolerably clear that Bazaine, on the 31st, had determined to force his way to Thionville by the routes through Kedange and Malroy, but that owing to the resistance he encountered he reverted that evening to the original plan of the council of Grimont of retiring within the fortress. This accounts to some extent for the non-advancement of the reserves into line on either day. According to his own statement, the tardiness in attacking arose from a wish that as many of the German corps as possible should be drawn to the right bank, both with the view of facilitating Macmahon's movements and lessening the danger of attack on his own left while advancing to Thionville. How to reconcile these views with the original intention of piercing the line of investment is not easy. It may, at all events, be fairly concluded that the battle was waged throughout with no one definite object, and, like all half measures, was not likely to be attended with success.

In consequence of the ineffective sortie of the 31st and the simultaneous defeat of Macmahon's troops at Beaumont, it became evident that any future attempt to gain the open field would be made in a southerly direction. The investing corps on the south and south-east were accordingly reinforced and strongly entrenched—the newly arriving XIII. Corps being placed so as to cover the road Metz-Solgne-Strassburg, and arrangements being made for the transfer, if necessary, of the bulk of the army to the right bank. Three weeks passed in absolute inaction within the fortress. After the 4th of September, a distribution of horse-flesh was substituted for the ordinary ration, and it became evident that a passive resistance could not long be prolonged. With a view, apparently, of securing what scanty supplies there might be in the vicinity, sorties were made towards Mercy-le-Haut, Colombey, Servigny, and Chieulles, from the 22nd to the 27th of the month. In proportion as the blockade continued, the chances of breaking out grew less. The energy and fitness for work of the French troops was much impaired, the horses of their mounted corps were diminished in number, and the investing works around the fortress were increasing daily in strength. By the end of the month Strassburg and Toul had fallen, and it appeared, in consequence, probable that any future sortie would be directed towards the Luxemburg frontier. The north-eastern portion of the line of investment was accordingly strengthened by the passage over the river of the X. Corps. A sortie was made towards Ladonchamps on the 2nd October, and repeated in considerable force on the 7th, but there does not appear in this instance to have been any intention of breaking through the blockading lines.

As a result of a council of war, held on the 10th inst., it was decided that efforts should be made to gain honourable terms of surrender from the enemy, and if unacceptable conditions were imposed, to make a final desperate effort to escape. Owing to the fall of the Empire, and the absence of any stable Government in the country, negotiations as to the terms of peace were carried on for some days. Defeated in the open, then invested, and driven back in every attempt to break through, the French army had at last to accept the unwelcome conditions offered it, there being no choice between surrender and starvation. By the terms of the capitulation, signed on the 27th October, the whole army of the Rhine, 173,000 strong, became prisoners of war, and the fortress of Metz, with all its stores and *matériel*, delivered over into the hands of the conqueror.

Capitulation of Metz, 27th Oct.

The investment of an army of 170,000 men in a powerful entrenched camp by a force but little stronger than itself, seems a matter requiring some explanation. With 140,000 men available to take the field from a central position against a line of investment 33 miles in extent, it was obvious that numerical superiority at any one point could always be gained. Till recently it has been generally admitted that a large entrenched camp, protected by permanent detached forts and possessed of a powerful field army, can only be invested with difficulty by a force at least three times the strength of the garrison. Modern conditions of warfare have, however, modified these views; chiefly from the great defensive power of the present fire-arms, when combined with earth

entrenchments, and the facilities for massing troops afforded by telegraphs and railways. When the *ground is favourable* for investment, it seems possible to blockade an army with a force less then double its strength, provided *sufficient time* is allowed to throw up effective lines of circumvallation. On the other hand, it appears that the vicinity of these powerful camps is, instead of a protection, a great danger to the large armies of the day, whether used as a base or as a tactical support. If of necessity an army is driven within the detached forts, it would seem that its proper object should be so to use its central position as to render the complete investment impossible—in other words, to wage a series of offensive battles at the first commencement of the blockade. By holding the ground gained in each effort till the mass of investing troops came to the attack, and then taking the offensive against another portion of the investing circle on the interior lines naturally possessed by the besieged, a blockade by any but very superior forces would be rendered very difficult. If, however, in lieu of an army, an entrenched camp has, besides its regular garrison, an effective field force of 30,000 or 40,000 men, it will be apparent that the place, if near any hostile lines of communication, will have to be invested, and that the blockade must, on account of the ground to be covered, be carried out by a very large force. According to these views, Bazaine, when once within the detached forts, had two courses open to him—either to pierce the lines of investment and gain the open country (leaving a powerful garrison within the fortress), or to take such vigorous offensive measures immediately after the 18th August as to prevent the effectual closing of the blockading lines. The battle of Noisseville appears the only serious effort that was undertaken; but the successes gained in it were not followed up, nor his superiority in numbers utilised. Whether the intended sortie towards Thionville was judicious, is a matter of opinion. If that fortress had been gained, it is undoubted that the army of investment would have followed him, and forced him to give battle in a position critically near the Luxemburg frontier. The most feasible quarter for a sortie seems to have been to the south and south-east; and that an effort in these directions could not have been stopped—at all events at the commencement of the investment—seems evident enough from the perusal of the German orders. What would have been the ultimate fate of the escaped army it is difficult to state; but assuming the worst, its capture would not have entailed the loss of the Metz forts.

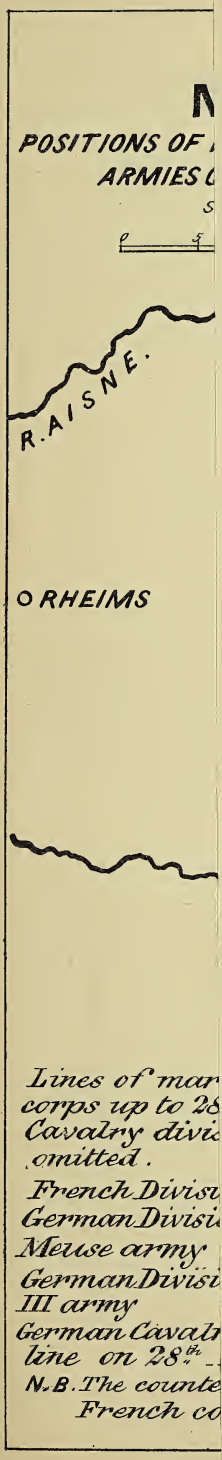
The charge of treason made against Bazaine has scarcely been proved; but, at the same time, it cannot be denied that his despatch to Macmahon was most misleading, and conveyed an idea he had little intention of following out. The whole tenor of his conduct in the defective arrangements made for passing from one bank of the river to the other, the deliberate concealment for a week of his knowledge of the movements of the Army of Chalons, and the deceptive statements about lack of warlike stores, led inevitably to the conclusion that he had at no time any strong desire to quit the vicinity of the detached forts. Whether this tendency to immobility resulted from any political plan for personal aggrandisement, or was merely the natural consequence of fearing to

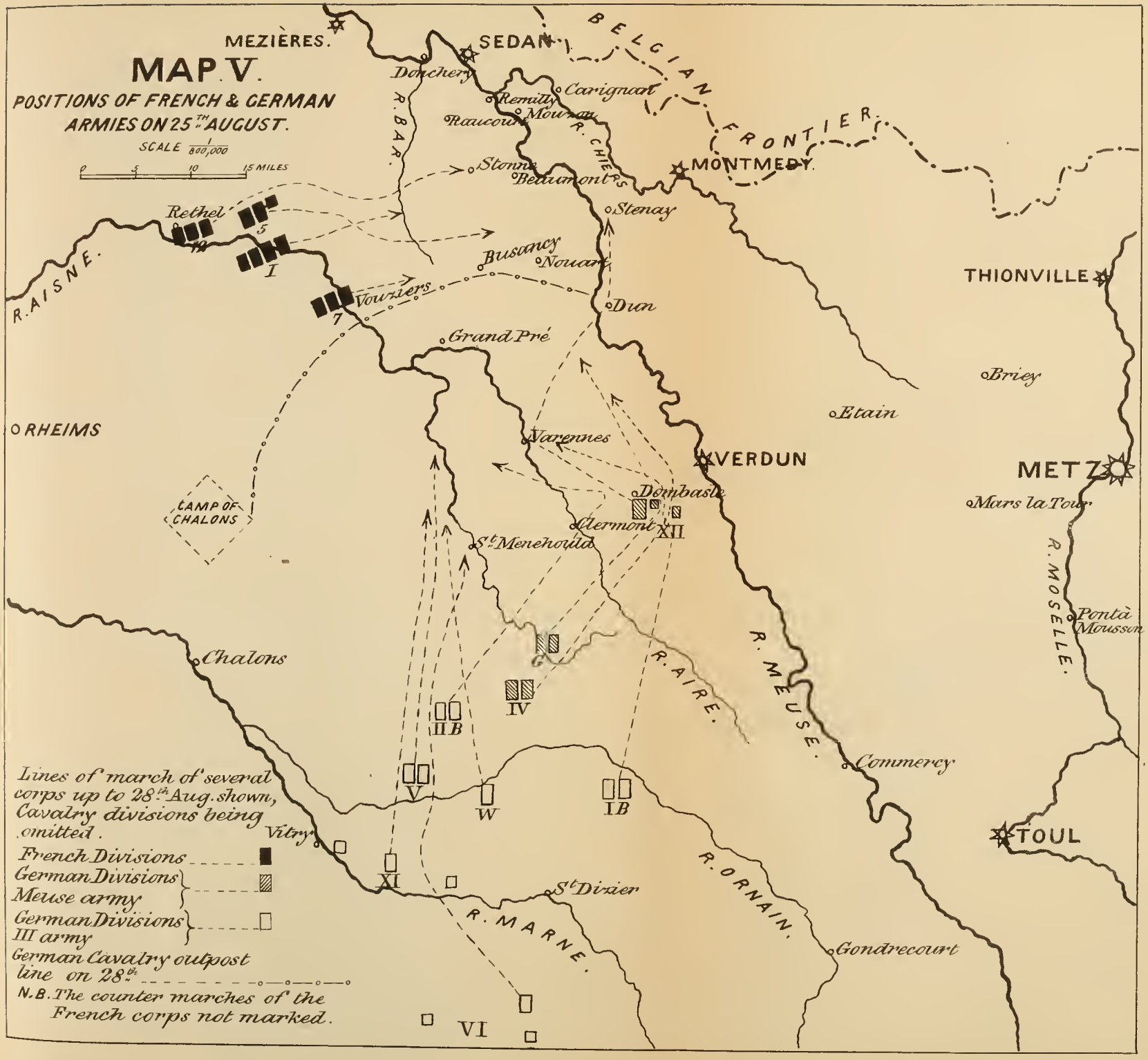
lose by defeat an already acquired military reputation, is a matter for dispute. It is surely unnecessary to impute the disgraceful charge of betraying his country to the well-known French Marshal. A man by nature confident; paralysed by the untoward course of events; unable to cope with surrounding difficulties; unwilling to admit, even to himself, his incapacity; might take refuge with careless *insouciance* in the policy of remaining quiet till fortune again smiled upon him. The consequences were, however, most disastrous. Macmahon would undoubtedly have not undertaken his perilous flank march unless he had been assured of the co-operation of the Metz Army. Even, however, if a union had been effected to the north of the Argonnes, the position would still have been most critical, considering the nature of the country and the close proximity of the Belgian frontier.

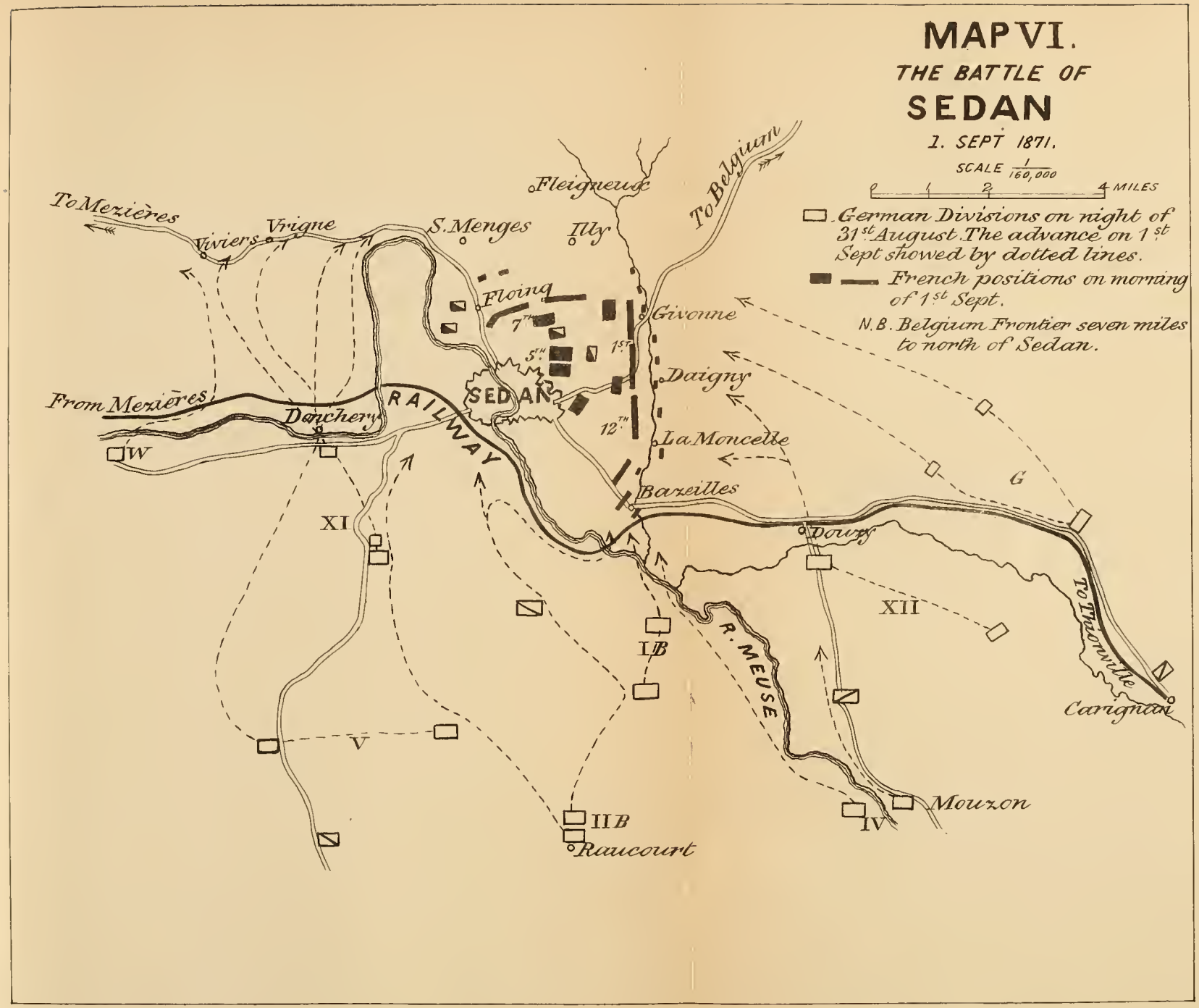
The news of the surrender of the whole Army of the Rhine spread consternation throughout the country. With the capital invested, and the entire regular army made prisoners of war, the situation appeared desperate. The Provisional Government, which had taken up its headquarters at Tours in the middle of September, had, with a view of exciting the spirit of the nation, painted the situation of Bazaine in most glowing colours, and the utter collapse of their imaginative hopes was the more painful. Futile endeavours to obtain peace were made at the end of October, but the pride of the French nation was not sufficiently humbled to allow the acceptance of the unwelcome conditions offered, and a stern spirit of resistance to the bitter end was engendered throughout the provinces. The entire north-east of France was (with the exception of a few fortresses) at this period in the hands of the invader, and his whole attention was naturally directed towards the capture of Paris and the repulsion of any efforts to effect its relief. Reviewing the situation for the moment, it will be noticed that the German armies, sweeping over a broad zone of country, had gained the centre of France. From the enormous mass of men brought into the field, it is apparent that the regions they passed through must have been speedily denuded of provisions, and that, from the hostility of the unconquered provinces, it was incumbent to fall back for supplies on the father country. To meet this contingency a general Etappen Inspection was appointed to each of the armies at the commencement of the campaign, the principal duties of which were the maintenance in good order of all the lines of communication, the collecting and forwarding of supplies, and the removal of sick and wounded to the rear.

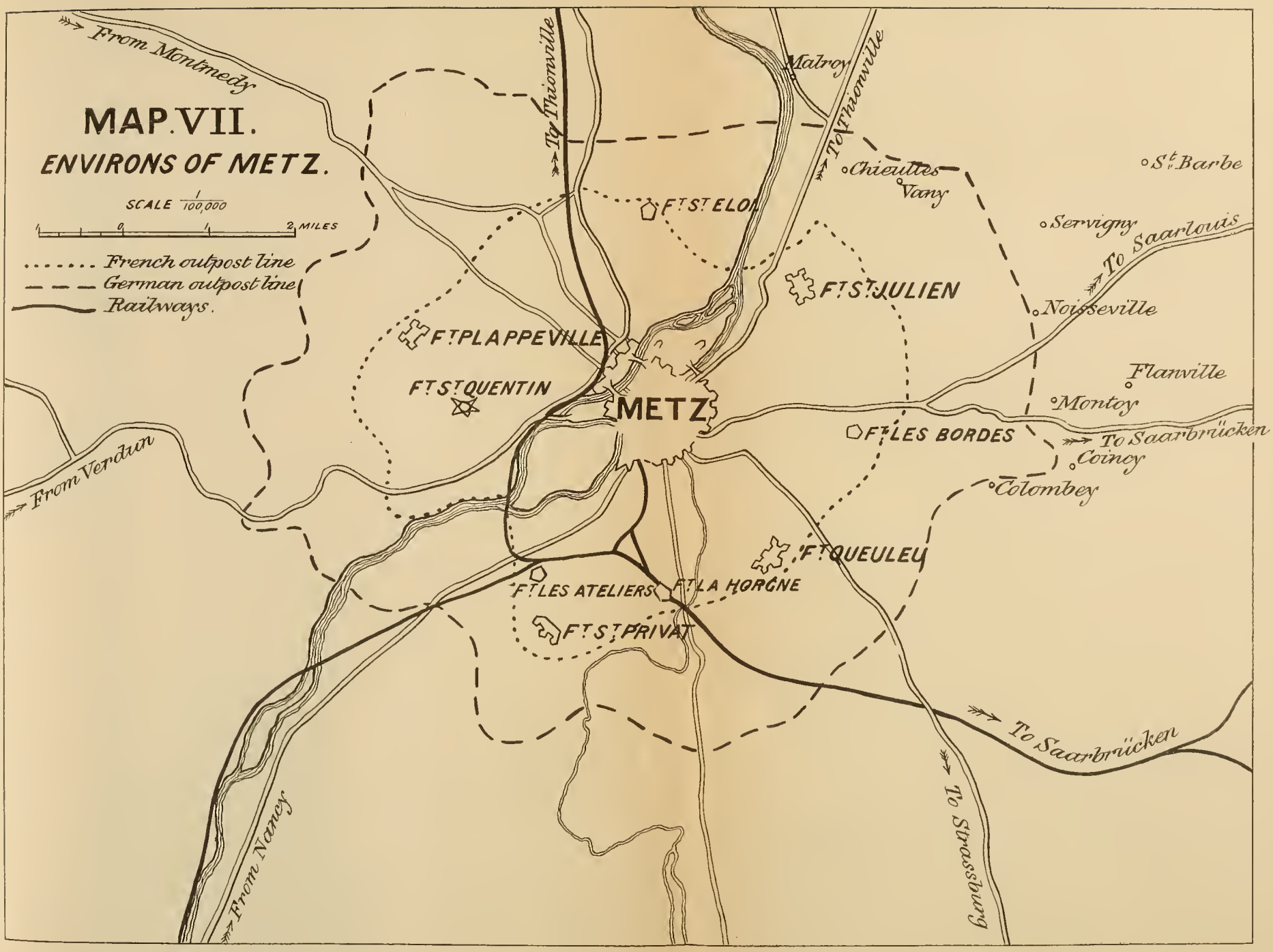
31st Oct.

As the armies advanced, large magazines were formed at the principal stations of importance along the lines of railway. These again were, for convenience of issue, connected with smaller depôts, the most advanced of which were one day's march in rear of the troops. The available resources of the country passed through were collected at these several points, and from them transferred by a regular chain of civilian and military transport to the troops themselves. As the armies advanced westward, and the regions traversed became exhausted, recourse had to be made to Germany to forward the requisite supplies. A consideration of these facts will make apparent the prominent part played by railways in this campaign, and show how very dependent the various military


N
POSITIONS OF
ARMIES
R. AISNE.
RHEIMS
Lines of mar
corps up to 28
Cavalry divi
omitted.
French Divisi
German Divisi
Meuse army
German Divisi
III army
German Cavalr
line on 28th
N.B. The counte
French co


MAP V.
POSITIONS OF FRENCH & GERMAN ARMIES ON 25th AUGUST.
SCALE 1/800,000
0 5 10 15 MILES
MEZIÈRES.
SEDAN
BELGIAN FRONTIER
Donchery
R. BAR.
Remilly
Carignan
Raucourt
Mouzon
R. CHIERS
MONTMEDY
Stonne
Beaumont
Stenay
Rethel
5
12
I
Busancy
Nouart
R. AISNE.
Vouziers
7
Dun
THIONVILLE
Grand Pré
Briey
Etain
RHEIMS
Varennes
VERDUN
METZ
Dombasle
Mars la Tour
CAMP OF CHALONS
Clermont
XII
St. Menehould
R. MOSELLE.
Pont à Mousson
Chalons
R. AIRE.
R. MEUSE.
IV
II B
Commercy
V
W
IB
TOUL
Vitry
XI
St. Dizier
R. ORNAIN.
R. MARNE.
Gondrecourt
VI
Lines of march of several corps up to 28th Aug. shown, Cavalry divisions being omitted.
French Divisions
German Divisions
Meuse army
German Divisions
III army
German Cavalry outpost line on 28th
N.B. The counter marches of the French corps not marked.


MAP VI.
THE BATTLE OF
SEDAN
1. SEPT 1871.
SCALE 1/160,000
0 1 2 4 MILES
German Divisions on night of 31st August. The advance on 1st Sept showed by dotted lines.
French positions on morning of 1st Sept.
N.B. Belgium Frontier seven miles to north of Sedan.
To Mezières
Viviers
Vrigne
S. Menges
Fleigneux
Illy
To Belgium
Floing
7th
5th
1st
12th
Givonne
Daigny
La Moncelle
Bazeilles
SEDAN
From Mezières
Donchery
RAILWAY
W
XI
V
I B
II B
Raucourt
R. MEUSE
Douzy
XII
IV
Mouzon
G
To Thionville
Carignan


MAP. VII.
ENVIRONS OF METZ.
SCALE 1/100,000
1 0 1 2 MILES
French outpost line
German outpost line
Railways.
From Montmedy
To Thionville
To Thionville
Malroy
Chieulles
Vany
St Barbe
Servigny
To Saarlouis
Noisseville
Flanville
Montoy
To Saarbrücken
Coincy
Colombey
FT. ST. ELOI
FT. ST. JULIEN
FT. PLAPPEVILLE
FT. ST. QUENTIN
METZ
FT. LES BORDES
FT. QUEULEU
FT. LES ATELIERS
FT. LA HORGNE
FT. ST. PRIVAT
From Verdun
From Nancy
To Strassburg
To Saarbrücken

operations were upon the lines of supply. Shortly after the investment of Metz, the two lines of Weissemburg-Nancy and Saarbrücken-Metz were available as far as the Moselle valley, beyond which the single westward line was blocked by the fortress of Toul. The fall of this place on the 23rd September secured one main line of rail for the force investing Paris. Eventually, branch lines were enabled to be utilised, by the capture of the small fortresses north-west of Paris; but no further direct communication could be obtained with Germany till Mezières, Thionville, and Metz had fallen. The security of the lines of road and rail in the occupied districts was generally entrusted to men of the Landwehr, and the general peace maintained by the establishment of Governors-General for the various regions—officers entrusted with supreme military and civil powers. The general principle was maintained throughout that an enemy's country must support the troops of the invader. To gain the existing supplies, recourse was had to a system of forced requisitions—receipts being given for the value of all articles taken; but in some cases, especially towards the close of the war, an open market was found preferable. Where no supplies in kind were available, a tax in money was levied on the towns, to the amount required for purchase of provisions, which had then to be forwarded from the home magazines.*

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* Each corps had a military transport of 5 provision columns of 30 wagons each, carrying 4 days' provisions and marching with the troops. Connecting these columns to the nearest magazines of supply, were 5 other columns of 80 wagons each (entirely a civilian transport of country carts), carrying 6 days' provisions, and ensuring the replenishment of the military wagons. Each man, in addition, carried 3 days' reserve rations in his knapsack. The troops could thus, on an emergency, have, exclusive of the resources of the country, 8 days' rations to depend upon for certain—*i.e.*, one day's fresh and 3 days' reserve rations in knapsack, and 4 days' in the nearest provision columns.

AUTOGRAPH LETTER OF THE DUKE OF WELLINGTON.

The following communication has been received by the Secretary R.A.I., from Captain Denis W. Pack-Beresford, late R.A.:—

March 19, 1876.

My Dear Sir,—

Looking over some old papers of my father's, I came across the enclosed communication from the Duke of Wellington to my father, in 1812 (the latter at the time in charge of the troops in the trenches before Burgos), directing his retirement from the position.

It is interesting to us of the family, as shewing the confidential terms that then existed between the Duke and his subordinates. It also is interesting to the service, as being a direct communication from the Duke to a Brigadier in command, without reference to his staff.

Should you think it might be interesting to publish the letter in the "Proceedings," on my behalf, pray do so.

Believe me

Yours very truly,

DENIS W. PACK-BERESFORD.

Major M. Le Fer Taylor,
Secretary R.A. Institution,
Woolwich.

Niobrara October 21st 1812
½ past one P.M.

My Dear Pack

I am sorry to say that I am afraid I shall be obliged to give up our position here in consequence of the Intelligence which I have received from Genl. Hill, of the movements of the Enemy in the South; and unless I should receive a contradiction of the Intelligence I propose to march this night.

As soon as you will receive this letter you should send off the Baggage of the Troops with you by Quinta Buenas & Villalon to Grandeviney.

B. General Pack

If I should go I will send you
word, & in that case you will march
when the Moon will rise and will go
entering it by the side of the Trenches
into the Town of which you will keep
Possession as well as of the Trenches
till 5 o'clock in the Morning.

You will then march with the
Troops under your command by the
high Road of Valladolid to Franciscus.

The Troops in the Trenches should
evacuate the Horn Work first. They should
then evacuate the other part of the
Trenches; and they should proceed along
this side of the River to Villalon, where
they will cross, & join you. Your Brigade

the Spanish Infantry, & Lt. Browns
Pa. Mn. should be across the ~~Mine~~
before the Trenches will be evacuated;
leaving of the Latter only the Sentries
necessary & prevent the Enemy from
coming out of the Castle.

At a particular ~~time~~ moment & be fixed
shortly before 5 at which the last of the Trenches
are to be evacuated, the Mines in
the Horn Work must be exploded by
an Officer, who must be mounted &
rode away.

Ever Yours mortuarily
Wellington

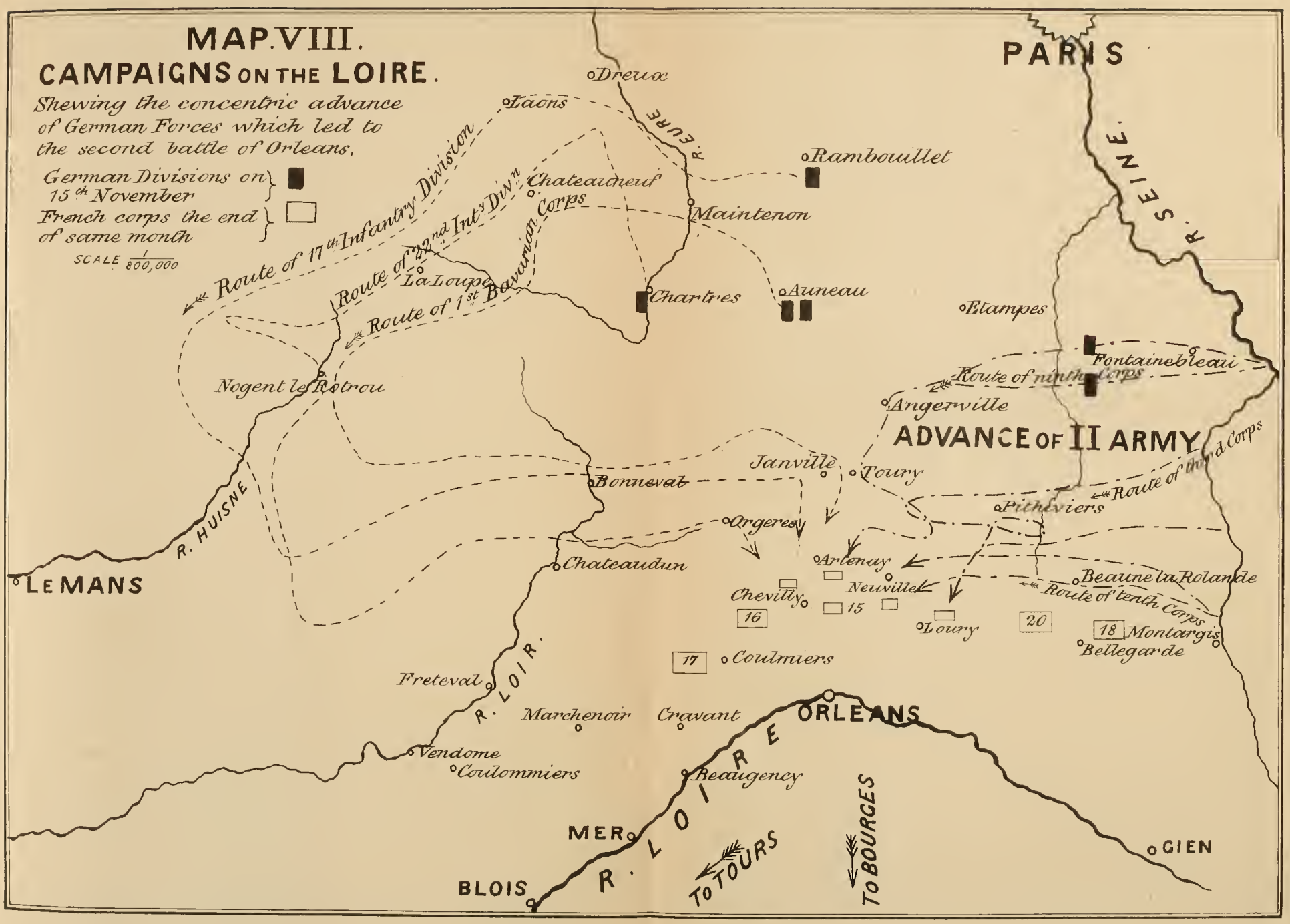
Let the Troops belonging to the
1st Division excepting those in the

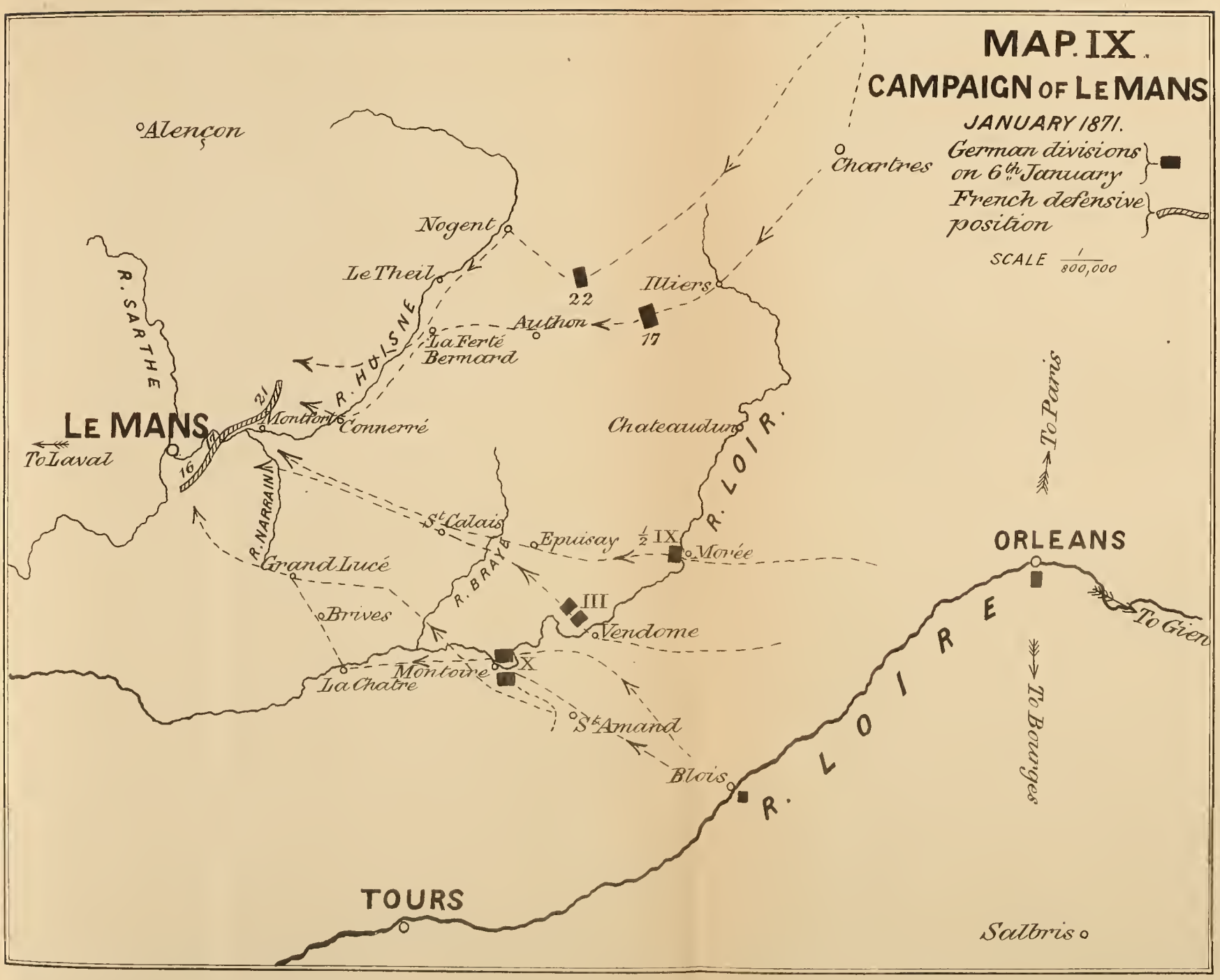
Nuncheryjoda then Division as it
will have Gamonal, & let there
of the 6th Division, excepting Col.
Brown do the same.

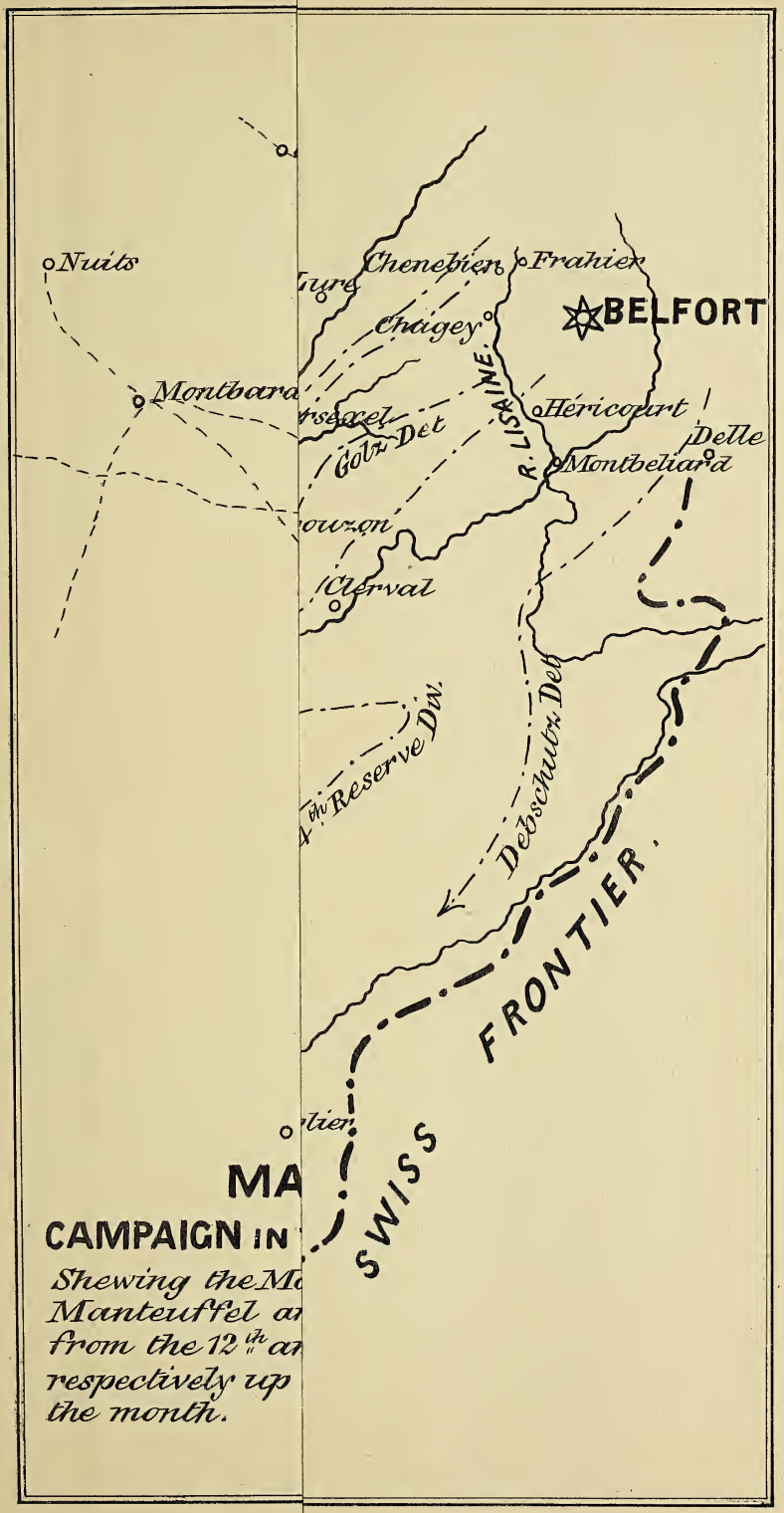
Brigr. General Pack

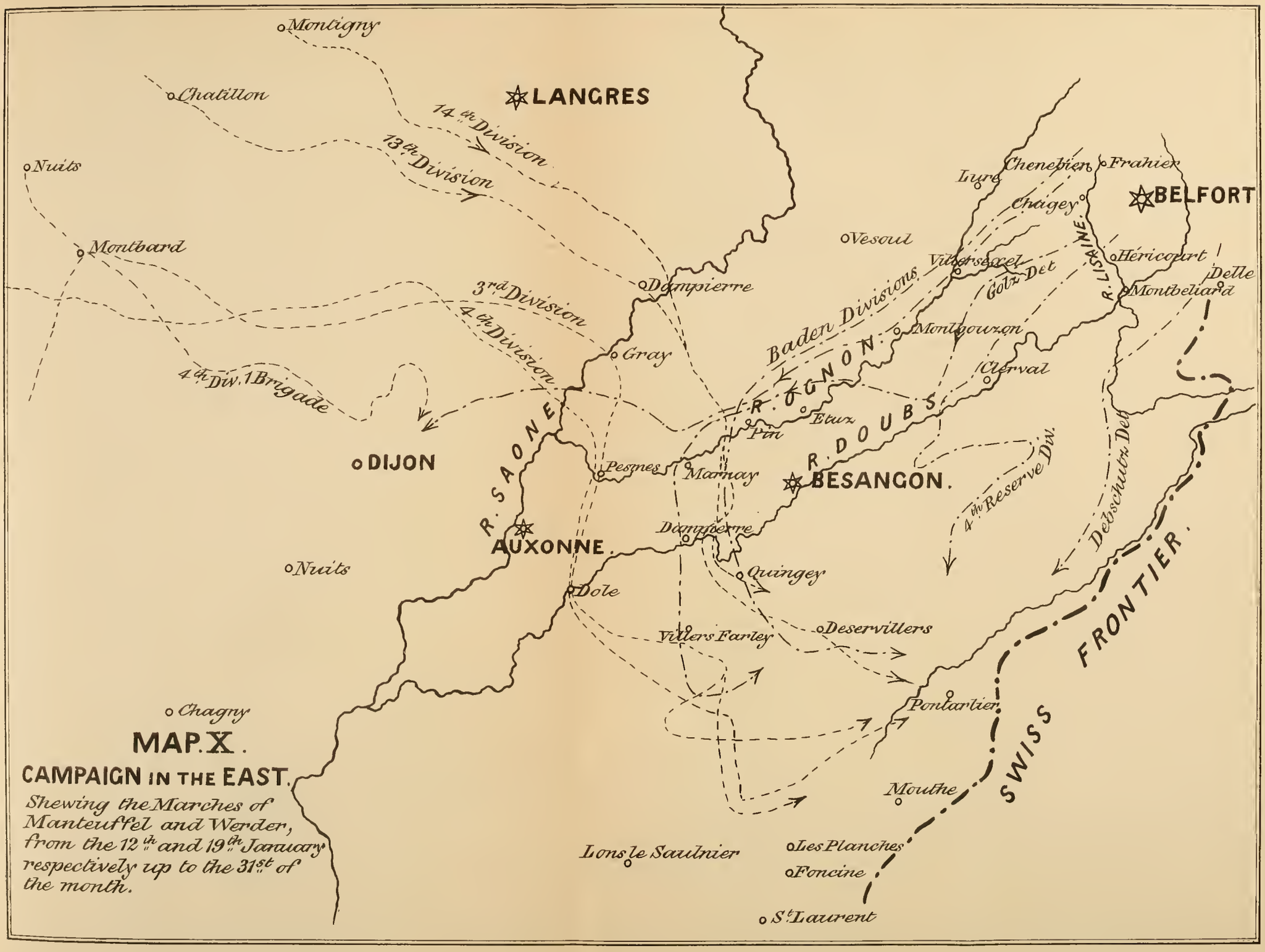
[illegible]

Wellington


MAP. VIII.
CAMPAIGNS ON THE LOIRE.
Shewing the concentric advance of German Forces which led to the second battle of Orleans.
German Divisions on 15th November
French corps the end of same month
SCALE 1/800,000
PARIS
R. SEINE
R. EURE
Dreux
Laons
Rambouillet
Chateaudeuf
Maintenon
Route of 17th Infantry Division
Route of 22nd Inf. Div.
Route of 1st Bavarian Corps
La Loupe
Chartres
Auneau
Etampes
Fontainebleau
Route of ninth Corps
Nogent le Rotrou
Angerville
ADVANCE OF II ARMY
Janville
Toury
Bonneval
Route of third Corps
Pithiviers
Orgeres
R. HUISNE
LE MANS
Chateaudun
Artenay
Neuville
Beaune la Rolande
Route of tenth Corps
Chevilly
16
15
Loury
20
18
Montargis
Bellegarde
17
Coulmiers
Freteval
R. LOIR.
Marchenoir
Cravant
ORLEANS
Vendome
Coulommiers
Beaugency
R. LOIRE
MER
TO TOURS
TO BOURGES
GIEN
BLOIS


MAP. IX.
CAMPAIGN OF LE MANS
JANUARY 1871.
German divisions on 6th January
French defensive position
SCALE 1/800,000
Alençon
Chartres
Nogent
Le Theil
Illiers
22
17
Authon
La Ferté Bernard
R. HUISNE
R. SARTHE
LE MANS
To Laval
21
16
Montfort
Connerré
Chateaudun
R. LOIR
To Paris
R. NARRAIN
St Calais
Epuisay
½ IX
Morée
ORLEANS
Grand Lucé
R. BRAYE
III
Vendome
Brives
To Gien
La Chatre
Montoire
X
St Amand
Blois
R. LOIRE
To Bourges
TOURS
Salbris

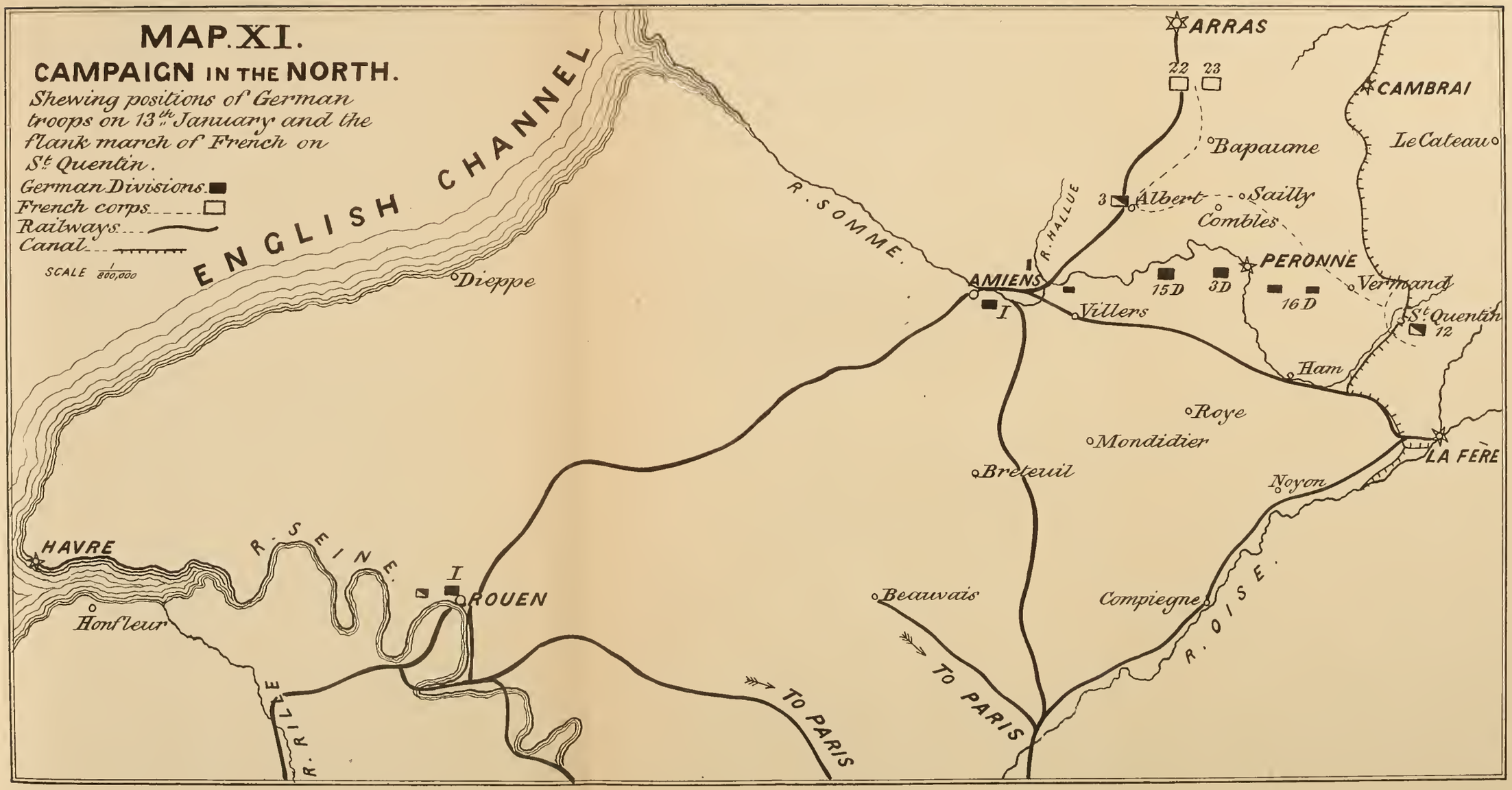

Nuits
Chenebier
Frahier
BELFORT
Chagey
Montbara
R. LISAINE.
Héricourt
Delle
Golz Det
Montbeliard
Clerval
4th Reserve Div.
Debschutz Det
SWISS FRONTIER.
MA
CAMPAIGN IN
Shewing the Mo
Manteuffel ar
from the 12th ar
respectively up
the month.



MAP. X.

CAMPAIGN IN THE EAST.

Shewing the Marches of Manteuffel and Werder, from the 12th and 19th January respectively up to the 31st of the month.


MAP. XI.
CAMPAIGN IN THE NORTH.
Shewing positions of German troops on 13th January and the flank march of French on St Quentin.
German Divisions
French corps
Railways
Canal
SCALE 1/800,000
ENGLISH CHANNEL
R. SOMME.
R. HALLUE
R. SEINE.
R. RILLE
R. OISE.
ARRAS
CAMBRAI
Le Cateau
Bapaume
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Sailly
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PERONNE
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St Quentin
Dieppe
AMIENS
Villers
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ACCOUNT OF AN EXPEDITION UP THE BOLAN PASS TO KHELAT TERRITORY, WITH MAJOR SANDEMAN, POLITICAL AGENT.

BY

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Affairs in Beluchistan and Kutchee being in a very unsettled state, owing to the differences between the Khan of Khelat and his chiefs, and grevious complaints having been made by merchants of numerous raids on their caravans of camels in passing up and down the Bolan Pass, a force was directed to proceed under one of our Political Agents (Major Sandeman) to afford protection to these merchants, and to open the Bolan Pass once more to traffic. I propose to give a narrative of this expedition; and in order to give an idea of the ground moved over, it will be remembered that Jacobabad is our military frontier station of Upper Sind, separated from the Beluch Hills and Bolan Pass by the barren plains of Kutchee, as also that the Bolan Pass is the recognised camel route to Khelat, Quetta, and Candahar. It will appear strange that the command of the escort or force should not have been given to a field officer. A rumour was spread that orders had been given that no officer senior to Major Sandeman was to go; but this was officially contradicted. As it was, the command of the force devolved on a Captain of the 30th N.I., and I found myself the second in command. The following force, consisting of some 900 men of the three branches of the service, comprising the escort, assembled on the 3rd April, 1876, at Jacobabad:—

One squadron of Punjaub cavalry, some 200 strong, commanded (unaided) by a Captain.

Two squadrons of the 3rd Regt. Sind Horse, some 350 strong, commanded by a Captain, with a junior Captain and four Lieutenants.

One wing of the 4th Punjaub Sikhs, 150 strong, commanded (unaided) by a Captain.

One wing of the 30th Regt. N.I., commanded by a Captain (who also commanded the force) and a Lieutenant.

One half-battery of the Jacobabad Mountain Train, commanded by a Captain (unaided), consisting of 2 smooth-bore $4\frac{2}{5}$-in. howitzers, 2 native officers, and 50 native gunners and muleteers, with 43 mules.

One medical officer in charge of the escort.

In the above remarks regarding the officers being "unaided," I

have not included the native officers, who, except under very "peculiar" circumstances, could never command a corps. As a matter of convenience in recording the march of the escort, I shall adopt a journal form.

4th April, 1876.—At 4 a.m. the force quitted Jacobabad and marched to Rojan (just beyond our frontier boundary); distance 12 miles. The baggage camels of the different corps were here paraded for inspection by a committee of officers, the weak and sickly ones being rejected and changed for strong and healthy animals; opportunity was also afforded for getting out anything forgotten or left behind at Jacobabad.

5th and 6th April, 1876.—At 6 p.m. on the 5th the infantry and artillery (followed at 8 p.m. by the cavalry), having struck camp, marched straight over the desert (34 miles) to Kunda, arriving on the 6th at 7.30 a.m. Guides showed us the road, which would otherwise have been difficult to find, owing to there being no track and a regular sea of sand. Fires were also lighted along the road to guide us. The infantry were rather fatigued, and suffered from want of water, though camels, loaded with filled leathern water bags, were sent on in front to stop at different stages on the road. The cavalry made camp about half-an-hour after our arrival. (For a description of the road, villages, supplies, &c., at the different encamping grounds, *vide* March Report annexed.)

7th April, 1876.—The infantry and artillery marched at 2 a.m. (the cavalry at 4 a.m.) to Makan Bela—distance, 16 miles—arriving at 8 a.m. (the cavalry about an hour later). The road was again over sand, and generally uninteresting.

8th April, 1876.—The infantry and artillery marched at 1 a.m. (the cavalry at 3 a.m.) to Bagh—distance, 22 miles—the whole force reaching camp at 9.15 a.m. But a delay occurred on this march. Bagh is the capital of Cutchee, and Major Sandeman wished us all to march in, in state; consequently the infantry and artillery were ordered to halt three miles short of camp till the cavalry came up, which delayed us nearly two hours. On their arrival the march was continued, and about a mile from Bagh a force of the Khan of Khelat's, consisting of a regiment of cavalry and one of infantry, were drawn up in review order facing the road, and presented arms to us, with full honors, as we passed. On making camp, a salute of 11 guns from a small battery was fired in honor of Major Sandeman; but as strict orders were given that none of our force were to be permitted to enter the town, or the place where the troops of the Khan were encamped, I was unable to inspect the guns, but from their report I imagine they may have been 3-prs.

9th April, 1876.—We halted at Bagh—a most unfortunate circumstance, as it turned out, for, unknown to us, cholera was raging in the place. In spite of our confining everyone to camp, bad water acting on the tired frames of the men speedily found victims for the disease, and the men began to drop. The recent long marches and want of sleep now

began to tell, and no appliances for filtering water were at hand. However, to remain was madness; so, after a "Council of war" on 10*th April*, 1876, at 2 a.m. the infantry and artillery, followed at 4 a.m. by the cavalry, marched on to Hagee-ka-Shur—distance, 14 miles. This was a trying march, as men kept falling out of the ranks, ill and dying. The litters were soon full, and many men were left behind under guards, to be picked up by the rear guard and baggage camels. Still the disease had its victims, who went to hospital to die. The doctor had a busy time of it, but worked with a will, to the admiration of the force. A cholera hospital was formed, and left here, under charge of a native doctor, and, still pushing on, the entire force marched the same evening (10th) to Pir—distance, 22 miles—arriving on the 11th at 8 a.m., after having dropped more men on the road. On this march we passed through the outer range of hills, and five miles from camp made Dadur—the outer entrance into the Bolan Pass. Here we had the blessing of good water from a clear running stream, but the disease still continued, so, tired as all were, we determined on pushing on, and the same evening (11th) at 10 p.m. we marched to Kirta—distance, 25 miles. We were now ascending the pass, up the bed of the Bolan river (shingle and stones), over which we repeatedly crossed, with high masses of rock on either side. The ascent was very gradual and barely perceptible, yet on reaching Kirta we found ourselves 1200 ft. above sea level, the temperature cool, a strong wind blowing, and a clear running river in the valley, where we pitched camp. All seemed in our favour, so we determined to halt here, both to rest the men and try to shake off the disease, which appeared to be on the decline. Another object in this halt was to allow the caravan of camels (some 4000) that we were escorting to push on up the pass, as the cholera was also amongst them, and no obstruction had occurred. Kirta is well up in the hills, which are quite barren, with no trees or vegetation. The river (the Bolan) is full of *maksur* (Indian salmon) which give good sport with either spinning tackle or the fly, and are excellent eating. These ran up to about 5 lbs., though in other places they run much higher. To the foot of the outer range of hills, near Dadur, my howitzers travelled easily on wheels, dragged by a team of three mules in single file—one in the shafts and two hooked on in front. Fourteen ammunition boxes (two on each mule) went per howitzer. On entering the pass into this outer range of hills, I mounted the howitzers on the mules' backs—one carrying the gun, another the carriage, and a third the wheels, side-arms, and shaft. My mules are generally speaking short and broad, averaging about 13 hands high. Even during the longest marches they showed no signs of fatigue. They were shod on the fore feet only.

13*th to* 19*th April*, 1876.—Halted at Kirta. The cholera entirely left us, though the heat in tents during the day was 110°. The hospital left at Hagee-ka-Shur arrived on the 19th. On the 15th the cavalry escorted Major Sandeman to a point 9 miles higher up the pass, information having been received that the camel-men were trying to evade payment of the prescribed fee of 8s. per camel, and our object

being to keep them well in front of us. The cavalry and Major Sandeman returned in the evening.

20th April, 1876.—The entire force marched at 12.15 a.m. to Bet—distance, 20 miles—arriving at 9.15 a.m. The road was very heavy, over shingle, and winding through the different valleys; a steady ascent. We came upon no water during this march, except on crossing the Bolan river at Bibinani, 9 miles from Kirta. On reaching Bet we again came on the river, running in numerous small channels and vanishing under ground. On arrival, we ascended a high plateau and pitched camp, 3000 ft. above sea level. A violent gale of wind was blowing.

From 21st to 24th April, 1876.—Halted at Bet. The gale continued without ceasing till the night of the 24th, when it abated; so to protect the tents, we built up stone parapet walls round them. Large blocks of snow-ice were brought into camp from the top of one of the neighbouring hills. The hospital camp (left behind at Kirta) arrived on the 24th. Some good ibex shooting was obtained here.

25th April, 1876.—Marched at 4.30 a.m. on to Doozan—distance, 13 miles. The road was very heavy, over rough shingle and huge blocks of rocks. Another steady ascent; the pass in many places being grand, with lofty perpendicular rocks on either side. Signs of vegetation here appeared—such as brushwood, dwarf trees, and wild flowers. Doozan is at the head of the Bolan river, which dashes out of the rocks, forming a very pretty waterfall. The hills were covered with flocks of sheep and goats. The natives say that the flocks are only brought down to the water every fourth day, the water in the grass otherwise sufficing. The camp was pitched on the road, ready to move on.

26th and 27th April, 1876.—On the 26th, at 2 p.m., having struck camp, we marched to the foot of a range of hills—distance, 15 miles. We first descended a very steep descent out of Doozan; but a working party having been sent on in front to prepare the road, we all got down safely. We then marched along a pretty green valley, reaching the foot of the range at 8.30 p.m., where we bivouacked for the night in the open, the cold being intense. We carried our drinking water with us on camels, having been told that we should find none; though we discovered afterwards that there was a well full of good water close to where we bivouacked, but invisible to us in the darkness. At 5 a.m. on the 27th (daylight) we prepared to ascend the pass, having given strict orders over night to a native officer in charge of a cavalry picket, stationed at the foot of the pass, that no baggage camels were to be allowed to enter. This man disobeyed the order (for which he was placed in arrest), and on entering the pass, we found it all blocked with camels. They were at once halted and the infantry ordered to push on to the top. I followed with my mules. There was merely a very rough mountain path, and I had much difficulty in getting up the howitzers—in many places having to dis-

mount them off the mules (also the wheels) and carry them on the gunners' shoulders. As it was clear that in the existing state of the road the camels with their loads could not come up, on reaching the top a strong working party was set to work under the European officers to prepare a road, by aid of which we passed up all the camels. We found the descent into the valley worse than the ascent had been, so another road had to be made. However, we got all down into the valley by 11 a.m., officers and men having been steadily at work for 6 hours. After a short halt, we marched on, over a dusty plain, to Mustoong (distant 30 miles from Doozan), arriving at 2 p.m., the men being very fatigued.

Now, as we formed a standing camp at Mustoong, I shall drop the journal form, and attempt to give a general description of the place, and a short account of what the escort did there.

Mustoong gives the name to a large valley. It is 5700 ft. above the sea level and some 60 miles from either Khelat or Quetta (also called Shawl). The valley is richly cultivated with fields of Lucern grass, wheat, barley, &c. There are also numerous orchards full of fruit trees —such as fig, plum, apple, peach, apricot, and mulberry. The vines also are very fine, and of a great age. The ground is undulating and hilly, intersected with ravines. The water is running and good, but frequently disappears under ground for considerable distances. Wild flowers grow profusely—such as crocuses, hawthorn, dog-roses, &c. There is no regular town, but the villages are scattered amongst the orchards, surrounded by high mud walls. There is a small mud fortress (*vide* March Report) in which the chief merchants live and transact business. The natives of Beluchistan are fine-looking men—tall, with long, black curly hair and beards. They are all armed with shield and matchlock, and capable of much endurance. The battery is surrounded by hills: one high one is called Chiltun, and is said to be 10,000 ft. above the sea level. The fort is, like most native works, built of mud, with walls loopholed for musketry, and weak in defence. Height of the walls about 16 ft., and breadth 4 ft. The entrance consists of a high archway, with a strong door of wood (there is no ditch), and is defended by a guard of the Khan of Khelat. The interior consists of a few narrow streets and a citadel, from the top of which a fine view is to be obtained. The Khan, when visiting the place, lives in the citadel. He also keeps his stud of horses and ponies in the fort. They average about 2 yrs. old, the prevailing colour being piebald. The horses in these parts, owing to the rich grass, attain a great height. A colt aged $1\frac{3}{4}$ yrs. stood 15 hands high. Magpies and ravens take the place of the perpetual Indian crow; conies are also numerous. On the 31st May, 1876, the Khan of Khelat arrived, to confer with Major Sandeman on political matters. He received a salute of 19 guns from my two howitzers. The following afternoon Major Sandeman received the Khan in grand durbar, when all our officers, European and native, were present. (I carefully abstain from all political affairs, as this is merely intended for a brief account of the movements of the escort.) The climate of Mustoong is pleasant and

dry; warm during the day, but cold at night. Twice a week we have sports for the soldiers—racing, leaping, assaults of arms, wrestling, &c.

18*th July*, 1876.—This day Major Sandeman, with a portion of the escort, started with the Khan for Khelat, proceeding by the Mungoo-Chur valley. On his departure, I fired another salute of 19 guns from my howitzers.

20*th July*, 1876.—This morning, at 2 a.m., the remaining portion of the escort marched to Shiriab—distance, 14 miles—arriving at 7.15 a.m. This place gives the name to the valley through which our route lay, and which is parallel to the Mungoo-Chur valley, but separated from it by a high range of hills. During the afternoon, a severe thunderstorm with heavy rain burst over the camp and wet the tents, so we halted at this place on the 21st, and on the 22*nd July*, 1876, at 3.30 a.m., we marched in a southerly direction down the valley to Kaneti—distance, 9 miles. Arrived at 6.30 a.m.

23*rd July*, 1876.—At 4 a.m. marched down the valley (still south) to Zurdub Kazez—distance, 12 miles. Arrived at 8.20 a.m. An accident occurred on this march. In crossing a narrow bridge (unprotected with parapets) one of the spare mules (happily unloaded) shied, and fell into a deep ravine. By aid of ropes, and cutting away the embankment, we got the animal up, and it escaped with a few scratches. This caused some delay.

24*th July*, 1876.—At 4.15 a.m. marched to Berinchanow—distance, 8 miles. Arrived at 6.30 a.m. Shortly before reaching camp, the Shiriah and Mungoo-Chur valleys meet in a large plain, in the middle of which is a detached hill called Berinchanow, which gives the name to the encamping ground. Except at the encamping grounds, the Shiriah valley is very little cultivated. The soil is generally sandy and covered with brushwood, with occasional patches of jungle. A small running stream passes along the valley, but the best water comes from springs from the hills on either side, or underground tunnels (*karezes*). Small game abounds—such as hares, blue pigeons, and *chekaw* (hill partridge).

25*th July*, 1876.—Remained in camp till 9 p.m., when, the tents having been struck, we commenced a march to Giranee—distance, 22 miles. Arrived at 6 a.m. on the 26th. A very trying march, and being very dark I could not see much of the road, which appeared to continue south, and to be a prolongation of the Shiriah valley. On reaching camp, the Khan of Khelat presented each of our officers with a bullock-load of grass and one of firewood. He also sent some new hill potatoes for the mess. Giranee—so called from the name of a stream running through the valley—is a circular basin surrounded by hills, and is 1½ miles from the small village of Zeazut and about 8 miles from Khelat. The elevation above sea-level is 6600 ft.

27*th July*, 1876.—Halted at Giranee, and as a trooper of the 3rd Regt. of Sind Horse died of cholera this morning (he was attacked on the

march yesterday), we may probably remain in this place. The road from Mustoong was level and good, and a field battery could have trotted most of the way.

As we are likely to remain here for some time, I propose to bring the present narrative to a close; but if, as is probable, we move on to Khelat and Quetta, and return to Jacobabad down the Mula Pass, I will on a future occasion endeavour to give a description of those towns and the pass, which will form a sequel to the present narrative.

The enclosed Report of the March goes into details as regards the route, encamping grounds, &c.; and the rough map, prepared under great difficulties, may perhaps prove of service in illustrating the ground traversed and places of interest.

CAMP, GIRANEE, NEAR KHELAT,
4th August, 1876.

Report of the March from Jacobabad to Hagee-ka-Shur of the Jacobabad Mountain Train, on Escort with Major Sandeman, on Special Duty.

Date.	Name of halting place.	Time of mar.	Time of arrivl.	Distance.	Remarks on road:— Made or unmade, cart or cattle, good or bad, &c.	Remarks on camping ground:— High or low, open or confined, clean or dirty. Supplies, water, forage, &c.	Remarks as to time and place of appearance of cholera, fever, or any other disease.
1876.							
Apr. 4th.	Rojan.	A.M. 3.0	A.M. 7.30	mls. 11	Made road (unmetalled), light and sandy soil, bridges over irrigation, and also broken. Fit for passage of all arms. Flat country, partially cultivated. Guns drawn by mules.	Formerly a village and mud fort, now ruined by floods and deserted. Encamped on side of road E. of old fort (usual encamping ground is beyond). Rather below level of surrounding country. Formerly open, but now enclosed by jungle. Frequently used by Kafilas, and therefore dirty. Two pukka wells (the old one has the best water). Forage procurable.	Nil.
Apr. 5th.	Halted at Rojan.						
Apr. 6th.	Kunda.	P.M. 6.0	A.M. 6.45	33	No road, camel track, used by carts. Goes across desert in which there is no water. Formerly the plain was quite barren; good marching now. Low scrub and road cut up by flood water. Guns drawn by mules.	Kunda is a large village. There is abundance of open ground for camping. Water from a tank good and usually plentiful. Supplies and firewood scanty. Grass procurable in small quantities.	Nil.
Apr. 7th.	Makan Bela.	A.M. 2.0	A.M. 7.45	16	Camel and cart track, mostly along the right bank of Naree. This stream is divided into several channels, and dry most of the year. On its course are many villages (*wallee*) and some cultivation. Passed Gahee Khan at 5 miles, Synd-Sa-Gote 5½, Sajananee 8 miles, then Saltun-Shah-Mirpur at 12 miles (1 mile to E.), and at 13½ miles Kaisun-ko-joke (2 miles to W.) The Naree is crossed between the first and second named, 3 ft. deep, 30 ft. across (dry). General direction of route northerly. Marching easy. Guns drawn by mules.	Camped on left bank of the Naree, opposite village and S. of a walled enclosure with trees in it (the Bela). Plenty of open ground. Water from pools in bed of Naree, and good. Firewood scanty. Grain (*janaree*) in small quantities. Forage fairly abundant. The bed of the Naree is here about 50 ft. broad and 6 to 7 ft. deep.	Nil.
Apr. 8th.	Bagh. (Total distance to town = 8 miles).	A.M. 1.0	A.M. 9.45	25	Pass to right bank of stream by easy crossing. The route lies over open and barren plain, slightly undulating, last 5 miles a steady ascent. At 11 miles village (Machi). The guns drawn by mules.	Bagh is a walled town. Population said to be 8000. Camping ground 1 mile to N. from town and beyond tank. It is on right bank of the Naree, which is here dammed. On this occasion the dam was opened, to let down water to Kunda. Water from pools. Supplies indifferent. Forage procurable.	On the 9th April two cases of cholera occurred, and both proved fatal.
Apr. 9th.	Halted at Bagh.						
Apr. 10th.	Hagee-ka-Shur.	A.M. 2.0	A.M. 7.30	15	Route is a camel-track, leading nearly due N. A few small water-courses are crossed. At 3 miles Biamt of Tair-Ghazi. Hence, gentle ascent all the way. No villages, barren open country, thinly sprinkled with bushes, very little cultivation. Easy marching. The sandy soil here begins to be mixed with stones. Guns drawn by mules.	Village is large, situated on right bank of Naree, and surrounded by a good mud wall. It belongs to the Sherwarri Brahuis. Camping ground on present occasion about 1 mile W. of village, on sandbank of and close to Naree, which is here 80 yds. wide and 10 to 12 ft. deep. Bottom, hard sand, with pools. Abundance of open ground nearer the village. Water from Naree but indifferent. Supplies and forage scanty. Firewood plentiful.	Upwards of 25 admissions to hospital from cholera, many men being attacked during the march from Bagh. Type unsettled.

Report of the March from Hagee-ka-Shur to Kirta of the Jacobabad Mountain Train, on Escort with Major Sandeman, on Special Duty.

Date.	Name of halting place.	Time of mar.	Time of arrival.	Distance.	Remarks on road:— Made or unmade, cart or cattle, good or bad, &c.	Remarks on camping ground:— High or low, open or confined, clean or dirty. Supplies, water, forage, &c.	Remarks as to time and place of appearance of cholera, fever, or any other disease.
Apr. 11th.	Pir, (mouth of the Bolan Pass.)	P.M. 11.0	A.M. 7.45	mls. 22	No road, camel track, which on leaving camping ground at Hagee-ka-Shur leads through several miles of thick jungle. It is here narrow and winding. At 1 mile cross bed of the Moolawah, 100 yds. wide, hard bottom, descent very steep. Further bank easy. At 3 miles cross the bed of the Naree, similar in size and character to former, but an easy descent. Beyond the jungle is a bare open plain. At 12 miles the route enters the low range that divides the Dudur valley from Cutchee. The 14th mile is very difficult, and quite impracticable for artillery other than mountain. Beyond it is easy marching, the northern slopes being gentle and regular. The 13th and 14th miles are a defile, but the heights (low) can be crowned. From foot of the hills to Dadur is 4 miles. We advanced 2 miles, and turned half-left (N.W.) Easy marching to bed of Bolan river—dry, and shallow, and stony—which is several hundred yards wide. Beyond is camping ground. Guns carried on mules' backs.	Camping ground on right bank of southerly branch of Bolan river. It was quite dry, the water being led off for irrigation. No village, two large tombs, a few huts, and a walled garden. Very stony and inconvenient. Water from two irrigation streams to W. Dadur is a walled town, not so large as Bagh. The valley is cultivated and dotted with hamlets and walled gardens. Supplies and forage plentiful. Firewood scanty. Pir is not generally made a halting place, as there is good ground for camping near the town of Dadur. *Note.*—The route followed on this occasion is rarely made use of except by single travellers. It is the most direct, as by it Dadur is only 20 miles from Hagee-ka-Shur. Kafilas go from the latter place to Millri, 12 miles, and on to Dadur, 18 miles, total 30 miles. This is an easy route. On arriving at the defile before mentioned, we found it choked with baggage camels, and our march was consequently lengthened by fully an hour.	More than 40 admissions to hospital from cholera on the 11th Apr., very many cases occurring during the march. A severe dust storm, which lasted till the end of the day following, greatly discomforted the troops, and especially the sick. Type of cholera in several cases still very virulent.
Apr. 12th.	Kirta.	P.M. 11.0	A.M. 6.45	19	The mouth of the Bolan Pass is about 1 mile N.W. of the camping ground at Pir. The pass is the channel of the Bolan river, at the entrance about ½ mile wide, leads at first nearly S.W., average width from 300 to 400 yds., and tolerably straight. The enclosing hills are sandstone ridges, varying in height from 200 to 400 ft., difficult, but not absolutely impossible to crown and turn. At 7 miles (6 from mouth) is a spot called Kokan Dilani, where there is a good open space. It is 11 miles from Dadur. The marching is altogether over loose shingle, and the track crosses the river frequently. It was about 2 ft. deep and from 10 to 12 yds. wide. At Kokan Dilani the pass turns sharp to right (N.) and becomes a defile for about 2 miles. Width at first 100 yds., narrowing to 40. Cliffs of sandstone on either side that seem quite inaccessible. The stream is repeatedly crossed. Beyond this the pass expands again to 400 yds., and the path ascends a narrow stony plateau, then along a narrow valley ¾ mile wide, between high and sharp ridges. At 13 miles the track turns suddenly to left, over a low ridge, out of the Bolan valley, open but very stony. Several difficult nullahs, almost impracticable for artillery other than mountain. Guns carried on mules' backs. At about 16 miles from Pir, the Kirta valley opens out and the track divides, the left branch being the main Kafila road to Bibinani, and the right leads to the Kirta valley. The latter leads near a low range, in which is a hollow containing warm springs. This place is called Surmab, and 17½ mls. from Pir. Kirta is beyond the termination of this range, on the right bank of the stream. It was formerly a flourishing village, but is now ruined and deserted.	The force was camped on some rather high ground N. of the village. The river ran to the E. This spot is narrow and inconvenient. There is a considerable extent of good ground opposite to Gurwah. Near the encamping ground the river is a running stream of good size, but a mile higher up there is no water. No supplies are procurable. The river water is clear and sparkling, but disliked by the natives. Grass is found near the stream, but it is as a rule very coarse. Some is also procurable on the hills. Forage for camels is abundant. Firewood very scarce.	About 15 cholera admissions to hospital on the 12th Apr. Fewer cases on the march, but several terminated fatally. Infantry somewhat distressed, having to march in the teeth of a strong wind over a stony track, and being in want of rest after the three last marches.
Apr. 13th. to 17th.	Halted at Kirta.						On the 13th Apr. about 10 cholera admissions and still some deaths. On the 14th, 15th, and 16th April only a few admissions from cholera. Type very much less virulent. On the 17th Apr. a few admissions from cholera. Type decidedly less virulent, and very few fatal cases. *Note.*—The above sanitary remarks include the entire force.

Report of the March from Kirta to Bet of the Jacobabad Mountain Train, on Escort with Major Sandeman, on Special Duty.

Date.	Name of halting place.	Time of mar.	Time of arrivl.	Distance.	Remarks on road :— Made or unmade, cart or cattle, good or bad, &c.	Remarks on camping ground :— High or low, open or confined, clean or dirty. Supplies, water, forage, &c.	Remarks as to time and place of appearance of cholera, fever, or any other disease.
Apr. 18th. Apr. 19th.	Halted at Kirta.						On the 18th Apr. very few cases and deaths from cholera. On the 19th Apr. admissions from cholera ceased.
Apr. 20th.	Bet.	P.M. 12.0	A.M. 9.0	mls. 22	From Kirta N.N.W. over bare and stony plain. At 6 miles pass through Jalogin ridge by gaps 20 yds. long and 16 to 17 ft. wide. This can be avoided, as the range terminates half a mile to N. Next 2½ miles rough and stony, then a descent to river bed. Bibinani (9 miles) is a gap between two ridges. There is running water, and it is a usual halting place. Camping ground due north on raised ground, to left of water channel. Passing the gap, the route turns due N., up broad bed of Bolan river. At about 13 miles the route becomes quite open, but the track is very rough and stony. At 18 miles a small defile, a few hundred yards long and 20 broad. The sides are accessible. Hence the pass averages about 500 or 600 yds. in width for about 3 miles. There is then a space over ¾ mile broad. The river runs to right, under a cliff 80 ft. high. Opposite to this a considerable extent of open but very stony ground, where troops might encamp. The place is called Bet. This march being over loose shingle and rough stones, was very fatiguing, both to the men and mules. The guns were carried on the mules' backs.	On the present occasion the troops camped on the top of the cliff, and found plenty of flat, open, but stony ground. This place is the end of the Kirta valley, and can be reached directly from thence. There is running water in the river bed below, but it disappears a short distance lower down. The quantity and place of disappearance vary very much. On the present occasion it was so shallow that trenches had to be scraped in the shingle to water the mules. Several good paths give access to the plateau from below. One of these is quite practicable for field guns. The situation is high and exposed. A violent gale of wind blew during all the time we remained there. The water is reputed never to be less than on the present occasion. By clearing trenches, therefore, enough can be obtained for all purposes, as it flows very rapidly. Camel forage abundant. Grass found in moderate quantities on the hills. Firewood scarce. No supplies.	On the 20th Apr., on arrival at Bet, rather severe types of fever and diarrhœa appeared, probably caused by sudden chills from cold and violent winds, and the great difference in temperature between this place and Kirta. On the 21st, 22nd, and 23rd Apr. fever and diarrhœa still prevailed; but the cases were fewer in number, and the general health of the troops improved greatly. On the 24th Apr. the fever and diarrhœa abated, as the wind dropped.
Apr. 21st. to Apr. 24th.	Halted at Bet.						

Report of the March from Bet to Mustoong of the Jacobabad Mountain Train, on Escort with Major Sandeman, on Special Duty.

Date.	Name of halting place.	Time of march.	Time of arrival.	Distance.	Remarks on road:— Made or unmade, cart or cattle, good or bad, &c.	Remarks on camping ground:— High or low, open or confined, clean or dirty. Supplies, water, forage, &c.	Remarks as to time and place of appearance of cholera, fever, or any other disease.
Apr. 25th.	Doozan.	A.M. 4.30	A.M. 9.30	mls. 13	After descending to river bed, proceed up it northwards, and pass a gorge 300 yds. wide. The cliff (150 ft. high) can be crowned from the south. The gorge is half a mile long. Beyond, the river makes a sweep to the right. The track is nearly straight over a plateau. At 2 miles again descend into and cross bed of river (Bolan): shallow running water. Then for several miles over another plateau. To the right, lofty limestone ranges, distant 4 miles; to the left, the river, running in a deep bed, beyond which is a high mountain (Mahomed Ghuznee). At 6½ miles again reached river bed, which is here the head spring of the Bolan river (Sir-i-Bolan), issuing from a rock to left of track. Here the route turns westerly, and at 7½ miles becomes a defile, at first 80 yds. wide, between perpendicular cliffs 150 yds. high. These can be easily crowned *before* entering the defile. The ground above appears to present no difficulties to the movement of infantry. The defile is very narrow, lessening to 10 yds. or less, the containing walls being 300 ft. high. At 11 miles the pass forks—that to the left being the Bolan proper, the other leads to Doozan. The pass is here 150 yds. wide, but it soon narrows again. A winding defile of 1½ miles leads to the Duzan valley. At one spot this is almost choked by huge blocks of fallen rock. The marching being chiefly over loose shingle, was fatiguing. Guns carried on mules' backs.	The Doozan valley is nearly 2 miles long by ¾ mile broad. Immediately before entering it, there is a small stream of running water from a spring situated in a narrow ravine to the right. The water only runs a short distance, and disappears under the shingle. There is sufficient open ground to camp a large force; but it is very stony, and cut up by small dry water-courses. The valley is surrounded by high hills. To the south, however, there is a less elevated part, over which a path leads direct to the Bolan, about a mile distant. Water from the spring abundant and good. Forage for camels plentiful. Grass on the hills in tolerable quantity. Firewood less scarce than at the two previous halting places.	On the 25th & 26th Apr. fever and diarrhœa slightly less prevalent.
Apr. 26th and 27th.	Mustoong.	P.M. 3.0 26th	P.M. 2.30 27th *	26	From Doozan over the hill into the Bolan. Descent very steep. Field or horse artillery would have to unhook, and run guns down by hand. Next 4 miles narrow and winding, but heights accessible. Then a narrow valley, 500 yds. wide, lying S.W. and N.W. to W. This is bounded by a low range dividing from Dusht-i-beh Dowlet. This is crossed at a low part near further extremity of the valley. At 6 miles, Karlaki Kotal. The ascent is steeper than the descent, but it is not difficult. From hence the route lies over broad alluvial soil—the Dusht-i-beh Dowlet plain—quite flat, and capital marching. The plain is of very irregular shape, and divided by two ranges which nearly approach each other. Route lies through gap between them. At 10 miles, Darwaza. Near here is an old well, called Outram's Well. It was dry. Passing here, the track to Mustoong lies S.W., that to Sir-i-ab and Shawl (Quetta) N.W. At 11 miles, arrive at foot of range which closes plain to W. Before reaching it, there is to the left, about 1000 yds. from the track, a well 115 ft. deep, with a good supply of water. A few hundred yards beyond, is a small mud fort, belonging to Alladuna Koord. Two paths lead over the range: on this occasion the troops passed by the southernmost—which is extremely difficult, and quite impassable for other than mountain guns. The other path (not known at first) was used by some of the baggage camels, and is much easier. Having crossed this range, the route lies nearly due S., down a narrow valley about 3 miles long; it then turns rather to the W. and enters the very extensive plain of Mustoong. The marching is now over alluvial soil and sand, and heavy in parts. The town of Mustoong, surrounded by gardens and orchards, is quite invisible till nearly reached, as it lies at a low level. The road skirts the fields and gardens to the camping ground, which is S.E. of the town.	Mustoong is a considerable walled town, said to have a population of 6000. In it is a citadel (*miri*) in which the Khan of Khelat resides when visiting the place. The works are of the usual mud-wall type, flanked with towers. They are in tolerable repair, but are of no strength naturally or artificially. The valley is well cultivated: there are thousands of acres of wheat, barley, Lucerne grass, &c. It is studded with hamlets, thickset with walled gardens and orchards. It is difficult to find a good camping ground near the town; all the level ground being used for crops and cultivated. That used on this occasion was not very convenient, and quite unsuitable for a large force. Supplies abundant. Forage plentiful. Water abundant and very good. Firewood rather scarce.	From 27th April to 1st May, fever still prevalent; diarrhœa less so. Several days of somewhat severe dust storms and high winds. Some heat during the day, but nights chiefly.
Apr. 28th to May 1st.	Halted at Mustoong.						

* Actual marching, 9½ hours. Bivouacked in the open from 9 p.m. 26th till 6 a.m. 27th.

ON THE COMPARATIVE ADVANTAGES OF TIME FUZES AND PERCUSSION FUZES IN SHRAPNEL SHELL, AS SHOWN BY THE EXPERIMENTS AT OKEHAMPTON, AUGUST AND SEPTEMBER 1875.

BY

MAJOR F. LYON, R.A.

(*Assistant Superintendent Royal Laboratory.*)

THE Report of the Special Committee upon their experiments at Okehampton gives information upon the relative effects of the different projectiles employed, viz :—

Common shell, with percussion fuzes,
Abel's water shell, " "
Boxer shrapnel shell, " "
" " with time fuzes.

In making the comparison, it has been necessary to consider only those shell which were "effective"—an epithet which is applied (see p. 6 para. 12) to a shell "which bursts in a target, or within a reasonable distance in front of it," &c.

The following information has been extracted from the records of the practice, with the view of making a direct comparison between the value of time fuzes and percussion fuzes with shrapnel. Not merely the "effective" shell, but every round has been taken into consideration; for in such a comparison it would not be right to disregard a round because the time fuze happened to be bored too long, for the same shell with a percussion fuze might have been effective; nor should a percussion shell which has grazed too far be omitted, because the same shell with a time fuze, bored correctly, might perhaps have hit the object.

Table A shows the trials made with deliberate firing at ascertained ranges. The column headed "effects" gives the number of "dummies," "troopers," &c., disabled—not the number of "hits."

The "targets"—which are numbered—are described in pp. 43 to 48 of the Report.

The pages of the Report referring to each experiment are shown in italics :—

A.

16-*pr. M.L.*

Target No.	Range, yds.	Date.	Time shrapnel.		Percn. shrapnel.		Water shell.	
			No. of rounds.	Effects.	No. of rounds.	Effects.	No. of rounds.	Effects.
10	1500	9 8	18 (*56*)	57	18 (*56*)	21	18 (*56*)	19
10	2100	11 8	18 (*57*)	37	18 (*57*)	14	18 (*57*)	8
3	2950	13 8	18 (*60*)	109	18 (*60*)	84	18 (*60*)	82
Total			54	203	54	119	54	109
Effects per round.....				3·72	—	2·20	—	2·00

Table B shows trials in which the firing was not deliberate. The time occupied in each case is noted. The range was known :—

B.

16-*pr. M.L.*

Target No.	Range, yds.	Date.	Time shrapnel.			Percn. shrapnel.			Water shell.		
			No. of rounds.	Effects.	Time, mins.	No. of rounds.	Effects.	Time, mins.	No. of rounds.	Effects.	Time, mins.
5	1500	21 8	8 (*8 & 81*)	76	2	8 (*8 & 81*)	4	3	8 (*8 & 81*)	44	5
6	2030	23 8	12 (*9 & 82*)	6*	5	12 (*9 & 82*)	3	7	12 (*9 & 82*)	2	4½
9	1950	26 8	36 (*85*)	50	6	36 (*85*)	37	11½	35 (*85*)	31	14
4	2000	30 8 1 9	36 (*70*)	182	10	36 (*71*)	131	5	36 (*71*)	186	9
Total			92	314	—	92	175	—	91	263	—
Effects per round.....				3·41	—	—	1·90	—	—	2·89	—

* In addition, "wheels of carriage much injured; many grazes of bullet on gun and carriage; pit full of shell fragments."

Another comparison is shown below (Table C). In this case the time fuzes were made at short notice and as an experiment, and they had not previously been tried. They burnt for 15 seconds, and were graduated to ½ seconds :—

C.

16-*pr. M.L.*

Target No.	Range, yds.	Date.	Time shrapnel.			Percn. shrapnel.			Water shell.		
			No. of rounds.	Effects.	Time, mins.	No. of rounds.	Effects.	Time, mins.	No. of rounds.	Effects.	Time, mins.
4	3930	20 8 30 8	6* (77)	8	Salvo.	6 (77)	25	Salvo.	6 (76)	11	Salvo.
4	3930	20 8 30 8	12 (79)	17	2	12 (79)	33	2¼	12 (78)	34	2
Total			18	25	—	18	48	—	18	45	—
Effects per round.....				1·38	—	—	2·66	—	—	2·50	—

* The fuzes were bored too long.

48 rounds with time shrapnel were fired on 18th August (see p. 53); but these cannot be compared with percussion shells—none of which were fired, because the ground was unfavourable. Experiments No. 24 p. 83, and 26 p. 84, must also be disregarded, for the separate effects of each description were not noted.

From Tables B and C it appears that the time fuzes, when the range is known, do not cause delay in firing.

The following is a summary of the three tables relating to the practice with the 16-pr. :—

16-*pr. M.L.* (*summary*).

	Time shrapnel.		Percn. shrapnel.		Water shell.	
	No. of rounds.	Effects.	No. of rounds.	Effects.	No. of rounds.	Effects.
Table A.....	54	203	54	119	54	109
Table B.....	92	314	92	175	91	263
Table C.....	18	25	18	48	18	45
Total ...	164	542	164	342	163	417
Effects per round.....		3·30	—	2·08	—	2·55

The comparative trials with the 9-pr. of 6 cwt. are shown below :—

9-pr. M.L. of 6 cwt.

Target No.	Range, yds.	Date.	Time shrapnel.		Percn. shrapnel.		Water shell.	
			No. of rounds.	Effects.	No. of rounds.	Effects.	No. of rounds.	Effects.
10	1500	9 8	18 (55)	38	18 (55)	13	18 (55)	44
10	2100	11 8	18 (58)	33	18 (58)	21	18 (58)	16
3	3000	13 8	18 (59)	72	18 (59)	22	18 (59)	47
4	3540	30 8 28 8	6 (74)	60	6 (73)	13	6* (72)	0
Total			60	203	60	69	60	107
Effects per round				3·38	—	1·15	—	1·78

* The shell fell "over."

The ranges were known, and the firing deliberate.

48 rounds (see pp. 15 and 53) were fired on 18th August with time shrapnel; but the ground was unfavourable to percussion fuzes, and thus no comparison can be made.

On 25th August (see pp. 65 and 11) 48 rounds were fired with percussion shrapnel and water shell, but there were no time shrapnel for comparison.

A trial of time shrapnel against percussion shrapnel is described on pp. 17 and 18. The ground on which the target was placed was favourable to the action of percussion fuzes. In this instance, the number of "hits" on the target (No. 8, p. 45, representing infantry in close order) were counted. There were no dummy figures.

The ranges were unknown, and were changed four times; 7 minutes being allowed for firing at each range.

In this experiment (*vide* the following table) the percussion shells were fired much more rapidly than the time shells—a different result from that recorded when the ranges were known. (See previous tables.)

9-pr. M.L. of 6 cwt.

Target.	Range, yds.	Time shrapnel.		Percn. shrapnel.	
		No. of rounds.	Hits.	No. of rounds.	Hits.
No. 8.	2300	—	—	—	—
	2200	74 (17 & 68)	497	101 (17 & 68)	796
	1600	—	—	—	—
	1200	—	—	—	—
Hits per round			6·71	—	7·88

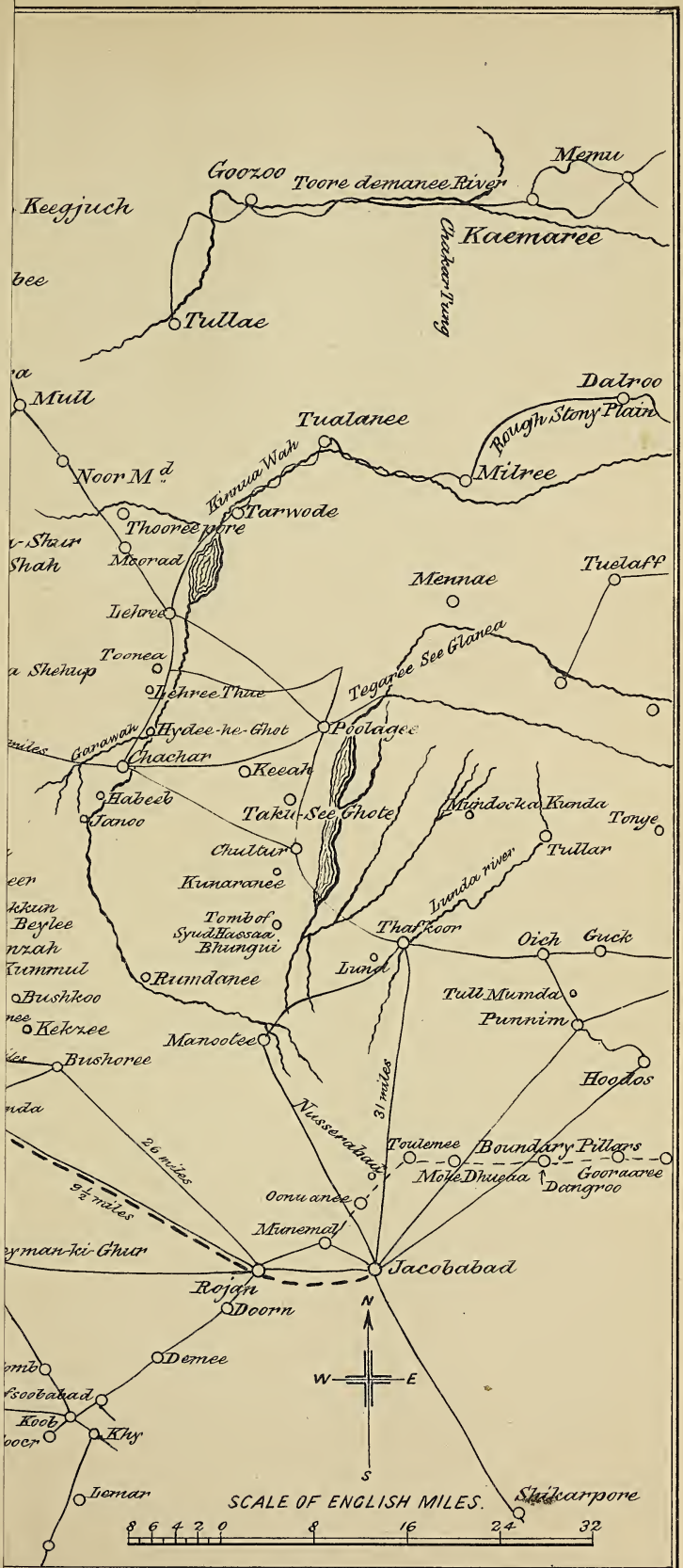
Out of the 497 hits with time shrapnel there were 294 "through," whereas out of the 796 hits with percussion shrapnel only 142 were through.

No water shell were fired on this occasion.

Upon the whole, the Okehampton practice shows that, when the range has been ascertained, shrapnel shell with time fuzes will produce greater effect than shell with percussion fuzes, and will be fired with equal rapidity.

The water shell with percussion fuze as used at Okehampton did not give any puff of smoke when bursting, and consequently did not assist in finding out the range. In destructive effect the water shell was superior to the shrapnel shell with the percussion fuze, but not to the shrapnel shell with time fuze, if compared in the manner adopted above, where the number of dummies disabled and not the number of hits has been considered.

DECEMBER, 1876.


Goozoo
Toore demanee River
Memu
Keegjuch
Kaemaree
Chakar Tung
Tullae
Mull
Dalroo
Tualanee
Rough Stony Plain
Noor Md
Kinnua Wah
Milree
Tarwode
Thooree pore
Moorad
Mennae
Tuelaff
Lehree
Toonea
Tegaree See Glanea
Lehree Thue
Hydee-he-Ghot
Poolagee
Garawah
Chachar
Keeah
Habeeb
Janoo
Taku-See Ghote
Mundooka Kunda
Tonge
Chultur
Tullar
Kunaranee
Lunda river
Tomb of Syud Hassaa Bhungui
Thafkoor
Oich
Guck
Luna
Rumdanee
Tull Mumda
Bushkoo
Punnim
Kekzee
Manootee
Bushoree
Hoodos
31 miles
Nusserabad
Toulemee
Boundary Pillars
26 miles
Mohe Dhueaa
Gooraaree
Dangroo
9½ miles
Oonu anee
Munemal
Jacobabad
Rojan
Doorn
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Lemar
SCALE OF ENGLISH MILES.
Shikarpore
8 6 4 2 0 8 16 24 32

Darwaza 5798 Ft
Dusht-i-beh Dowlet
Doozan 4495 Ft
Sir-i-Bolan
Tehree
Pringanal
Khurleehee Pass
Aligoom or Bet 2540 Ft
Deen Mahemed Scahna
Mustoong 5700 Ft
Shiriab
Amancota
Ispunglee
1695 Ft
Bibinani
Peak
Kirta 1081 Ft
Baradi
Javi
Kaneti
Goozoo
Mushhaff
904 Ft
Hokar Dilam
Dadur 700 Ft
Goolam Beluch
Keegjuch
Candahar Territory
Teebee
Nowshara
Mull
Goozoo
Toore demanee River
Memu
Kaemaree
Chakar Tung
Tullae
Dalroo
Rough Stony Plain
Tualanee
Milree
Zurdub Karez
Koh-i-Maran
Kysur
Mungoochi
Johan
Rodbar
Nowohara
Chibree
Millree
Bezee
Noor Md.
Tarwode
Thooree
Moorad
Beninchanow
Musjud
Hagee-ka-Shur
Sooltan Shah
Myhesen
Raelbar Pass
Woormukar Tukht
Takara
Leloree
Mennae
Tuelaff
Tunnee
Boodoo
Toonea
Mungal-ka Sheluop
Tehree Thar
Tegarbe See Glanea
Giranee
Zeaxut
Bagh 650 Ft
Hydee-he-Ghot
Poolage
Khelat 7000 Ft
Thulkoo
Chachar
Keeah
Habeeb
Jooroo
Taku-See Ghote
Mundocka
Kunda
Tonge
Tullar
Chultur
Kunaranee
Joorgee
6650 Ft Rodingo
Thorun
Nusseera bad
Makun Bela or Hajee-ka-Sheer
Syud-fu-Ghote
Tennea
Meerla
Mukkun Beylee
Tomb of Syud Hassaa Bhungui
Thafkoor
Oich
Guck
Cajote
Gurse Pass
Gurh Pass
Kessim ki-gota
Menpoor
Nonzah
Kummul
Rumdanee
Luna
Tull Mumda
Punnim
Panderam
Kazee Ismail
Hakim ki Glen
Bushkoo
Gajen
Khanwah
Tunjuranee
Kekzee
Manoolee
Hoodos
Kotree
Oidana
Brushoree
Nograma
Mowlaee
Meerpoor
Kunda
Tabahnee
Moshara
Gagua
Toulemee
Boundary Pillars
Mole Dhugda
Gooraaree
Doongroo
Gutt
Old Pungota
Peer Bhulter
Tamboo
Abad
Oonu anee
Minemal
Cajin 5000 Ft
Bapow
Kokoo Paneewant
Reyman-ki-Ghur
Jacobabad
Jull
Rojan
Doorn
Peesee
Paneewant
Door
Demee
Toonea
Tomb
Rufsoobabad
Koopk
Goomu Bapna
Koob
Toocr
Khy
Halachee
Dowani
Shadeehur
Khana
Lemar
Shikarpore
Peer Laka
Kumal Khan 4530 Ft
SCALE OF ENGLISH MILES.
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EXTRACTS FROM THE REPORT

BY THE

SPECIAL COMMITTEE ON RIFLED FIELD GUNS AND HIGH ANGLE FIRE

ON THE

ARTILLERY EXPERIMENTS AT OKEHAMPTON,

IN

AUGUST AND SEPTEMBER 1875.

[The following extracts from the Report of the Special Committee on Rifled Field Guns and High Angle Fire on the Experiments at Okehampton, in 1875, are published for the information of such of our members as have not been able to obtain copies of the Report itself. A limited number of copies of the Report are in the library of the Institution, and will be issued to members on loan, on application to the Secretary.]

1. With reference to War Office Papers $\frac{73}{\frac{3}{1146}}$ the Special Committee on Rifled Field Guns have now the honour to submit a Report on the artillery trials which were carried out by them at Okehampton in August and September 1875.

Before entering upon a detail of their proceedings, they deem it desirable to give a short account of the origin of these experiments.

On the introduction of the muzzle-loading field equipment, a difficulty was experienced in the production of an efficient percussion shell for muzzle-loading rifled guns, so that the Special Committee on Field Artillery Equipment for India (1869), on whose recommendation the muzzle-loader was introduced for that country, did not include this nature of projectile in the proportions recommended by them, although they considered "the question of segment shells and concussion fuzes one of great importance," and strongly recommended that it should be carefully worked out by a Special Committee.

Experiments with 9-pr. muzzle-loading segment shells, similar in character to the Armstrong breech-loading segment shell, and fitted with percussion fuzes to burst on graze, were subsequently carried out at Aldershot, with only partial success, by the Committee on Muzzle-Loading *versus* Breech-Loading Field Guns (1870).

In January 1870, the question of the provision of a trustworthy percussion fuze for field artillery was handed over to a Special Committee, who were subsequently directed (November 1870), in conjunction with the

Superintendent Royal Laboratory, to extend their enquiries in the direction of an efficient percussion shell for field service.

This Committee reported in March 1871 that the inferiority of the 9-pr. muzzle-loading segment shell tried at Aldershot had been fully established by repeated trials; that although the shrapnel shell could on an emergency be used as a percussion shell, the effects produced were not, in their opinion, such as would warrant its adoption for that special purpose; and that, of all the projectiles tried by them, a "bullet shell" submitted by the Superintendent Royal Laboratory, had given the best results.

They considered, however, that the experiments already made had been far too limited to admit of any definite recommendation being submitted, and recommended that the subject should be taken up by a Special Committee of artillery officers.

This led to the question being referred, in April 1871, to the present Committee on Rifled Field Guns and High-Angle Fire. They were directed to draw up a programme with a view of testing the comparative merits of the three kinds of shells (shrapnel, segment, and bullet), and to report whether there should be one or more projectiles of this nature in the service, and whether they should be fired with time or percussion fuzes, or with both.

2. The experiments instituted by the Committee for this purpose were carried on during the years 1872–73, and the results, so far as they went, shewed that the shrapnel shell, when used as a percussion shell, produced equal effects to either of the other two (bullet or segment), while as a time shell it was far superior to either of them.

Subsequently, further consideration of the bullet shell was postponed, pending a contemplated trial by the Committee on Explosives of 16-pr. common shell when burst under different conditions.

In January 1874, a report by the Committee on Explosives upon the results obtained by bursting 16-pr. common shells with small charges of dry gun-cotton, acting through water, was forwarded to the Committee, with instructions to report whether common shells charged in this manner would prove more effectual against troops than common shells charged with gunpowder.

Some preliminary experiments were made at Shoeburyness in March 1874, in which 16-pr. common shells filled with water, and fitted with a metal socket containing a small amount of dry gun-cotton and a detonator, were fired in comparison with ordinary common shells, both being burst by percussion fuzes. The results given by the "water shell" were decidedly superior to those produced by the powder shell, and these results were corroborated by further trial.

The Committee, however, were unable to fully test the comparative merits of the projectiles, as Shoeburyness did not afford a sufficiently extensive land range to test percussion shells against targets representing troops—indeed, throughout the whole of their experiments, the Committee had been impressed with the difficulty of drawing any definite conclusions from trials in which percussion shells were burst under circumstances, as to ground, that bore no relation to actual service.

With a view, therefore, to meet this difficulty, and at the same time to attempt the solution of many other problems connected with field artillery

which could not be satisfactorily treated on the ranges provided at the School of Gunnery, the Committee, in December 1874, caused a programme to be prepared for the purpose.

3. This programme was carefully considered, and on 21st April 1875 the whole scheme of the Committee was submitted to the Director of Artillery. They were of opinion that a series of experiments, conducted under circumstances analogous to what might occur on service, would settle many open questions as to equipment of batteries, comparative value of different projectiles, and the power of field artillery against recent infantry formations. The disadvantages of Shoeburyness as a site for the experiments were pointed out, and the superiority of such ground as Dartmoor advocated. It was also argued that although the experiments which had been carried on there in 1869 had led to a recommendation to withdraw all small capacity common shells from the rifled breech-loading field equipment, this proposal had not been acted upon, there being no effective percussion shell to take their place; thus, one-third of the projectiles now issued with 9-pr. R.M.L. guns are common shells of the same capacity as those tried and condemned at Dartmoor for the 12-pr. B.L. gun. The following were the points submitted by the Committee as likely to receive solution by means of the proposed experiments:—

(*a*) Rapidity and accuracy of fire of a battery coming into action at unknown ranges.

(*b*) The same with the distances measured by a range-finder, such as Nolan's.

(*c*) Effect of the fire of rifled field artillery against iron carriages, and the possibility of repairing in the field iron carriages injured by an enemy's fire.

(*d*) Comparative effect of the various projectiles with which the field artillery is now supplied, under different conditions of ground and distance.

(*e*) Suitability of the present mode of packing stores, with reference to facility of supply of ammunition to guns in action.

(*f*) The results of artillery fire against recent infantry formations, and the nature of projectile which under different conditions will produce the *maximum* effect.

(*g*) Lastly, it was urged that, apart from an experimental point of view, the trials, merely as tactical manœuvres for artillery, would prove most valuable to all concerned.

The Committee, in forwarding their proposals, requested that, in the event of approval, two of their members might be permitted to inspect the ground on Dartmoor and elsewhere, with a view to securing good ranges and suitable camping ground for the batteries.

4. In June 1875, the Director of Artillery, in conjunction with the Deputy Adjutant-General, R.A., submitted the Committee's proposals for favourable consideration, and the approval of the Secretary of State for War was notified to the Committee on the 18th June 1875.

It remained now to select suitable ground on Dartmoor; Colonel Wray and Major Noble were detailed for this duty. For reasons stated in their report, the moor in the vicinity of Okehampton was preferred. The neighbourhood lies very high, and the climate is in consequence very bracing and healthy; there is also a constant and abundant supply of excellent water, and to these two circumstances the absence of sickness among men and horses during the encampment was mainly due. Direct railway communication with Plymouth and Exeter proved important in connection with the stores and supplies required for the troops and the experiments; and although the railways had also the effect of inducing a constant influx of visitors to witness the experiments, such influx caused no inconvenience, the public readily complying with all orders issued to prevent danger or delay.

The camp was situated on enclosed ground held under lease (a moderate rent only was asked), and the shooting ranges were on ground belonging to the Duchy of Cornwall, which was readily lent by H.R.H. the Prince of Wales. Of the nature of the ground over which the practice was carried on, more will be said hereafter in describing the experiments, and in alluding to the instructional advantages to the men afforded by the month's encampment. It may be merely said here that the moor is very undulating, with occasional steep hills or tors, covered with boulders of rock, and that the ground was generally soft, and abounded with small but not dangerous bogs. The surface growth is chiefly heather and rushes; on the drier parts of the moor there is an abundance of furze, but there is a total absence of wood, except in localities where practice could not be carried out.

6. On the 17th July 1875, it was reported to the Quartermaster-General that all questions as to the use of the land had been satisfactorily arranged, and on the same day orders were sent to the General Officer Commanding in the Western District in accordance with the recommendations of the Committee. The batteries ordered to take part in the experiments were "E" Battery "E" Brigade, Royal Horse Artillery, 9-pr. R.M.L. guns from Exeter, under the command of Major T. N. Holberton, and "C" Battery 25th Brigade, Royal Artillery, 16-pr. R.M.L. guns from Devonport, under the command of Major G. W. Borradaile. Half a battery of the 10th Brigade Garrison Artillery, under Captain A. J. Shuttleworth, was also detailed for duties in connection with the magazine, ranges, and targets. A descriptive list of the ammunition, targets, &c., will be found in the Appendix.

7. The camp was formed on Monday, the 2nd August 1875, under the command of Lieut.-Colonel Tod Brown, C.B., Royal Horse Artillery.

8. The experiments carried on by the Committee may be best considered by arranging them into five classes, into which they naturally resolve themselves, viz.:—

Class I.—*The comparative value of various projectiles.*
" II.—*The effective zone of artillery fire.*
" III.—*The value of artillery fire against the most recent formations of infantry.*
" IV.—*Special experiments.*
" V.—*Range finding.*

(Class I.) The Comparative Value of various Projectiles.

9. The projectiles used by the Committee with both 9-pr. and 16-pr. guns were as follows:—

Common shell, with percussion fuze.
Abel's water shell, with percussion fuze.
Boxer-shrapnel shell, with percussion fuze.
Boxer-shrapnel shell, with time fuze.

10. In comparing one projectile with another, there are always contingencies to be considered which might invalidate any of the results arrived at. In such comparisons, also, it is impossible to eliminate what may be called "*eccentricity*" in the effects of various projectiles. Under what may seem as nearly as possible the same circumstances, the same projectiles will produce utterly different results. And the slightest difference in the hardness of the ground, the presence of a buried stone, or even causes more trifling than these, will often make a round ineffective which has otherwise all the elements of efficiency.

11. In narrating the experiments under this class, those will first be treated in which all four projectiles were employed together; and in addition to the number of hits made by each nature, the number of effective shells which produced them will be stated. An effective shell is one which bursts in a target, or within a reasonable distance in front of it—subject, however, greatly to the condition of the ground. A shell bursting beyond a target, or blind, or premature, is non-effective, and in making a comparison should be excluded from the calculation.

12. The positions for the dummies representing infantry were selected so as to afford them as much advantage as possible from the nature of the ground; the Committee being anxious to avoid giving any favour to the artillery fire, which might invalidate the conclusions arrived at, beyond that arising from the fixed and somewhat conspicuous character of the object fired at.

With this view, the President applied that an infantry officer of experience should be detailed to watch the experiments, and to point out anything which might seem disadvantageous to that arm in the placing of the targets.

The officer who was subsequently detailed from Plymouth for this duty, expressed his complete satisfaction with the arrangement of the targets made by the Committee.

The softness of the ground was generally unfavourable to the effect of artillery fire with percussion fuzes.

13. On the 9th August, series C of the experiments detailed in the programme was carried out, the target being No. 10. The firing was directed against the attacking line, which consisted of 100 wooden dummies, in rank entire, one pace between each; but any hits which were made in the supporting line or main body were also noted. It may be here stated that, except at short ranges, little injury was ever inflicted on the supports by ricochets or dispersion of shells aimed at the attacking line. On the 9th August, the chance of injuring the supports was further diminished by the guns being placed on a lower level than the brow over which the attacking line was advancing, which therefore appeared from the battery to be on the

sky-line, the supports and main body being on the reverse slope and out of sight.

14. This practice was commenced by the 9-pr. battery R.H.A., at a measured* range of 1500 yds. from the attacking line, the supports being 250 yds. in its rear, the main body 350 yds. in rear of the supports.

Eighteen rounds of the various projectiles were fired in succession, with the following results, the targets being examined and hits noted after each series :—

9-pr. R.M.L. Gun, 6 cwt., R.H.A.

Nature of projectile.	Number of dummies hit.			Effective shell.	
	Attacking line.	Supports.	Main body.	Number.	Hits per shell.
Boxer-shrapnel, time fuze.....	38	0	0	15	2·53
" percussion fuze ...	12	1	0	13	1·00
Water shell, " ...	41	3	0	14	3·14
Common shell, " ...	9	0	0	9	1·00

The 16-pr. battery then came into action and fired 18 rounds of the various projectiles at the same range and targets, with the following result:—

16-pr. R.M.L. Gun, 12 cwt., R.A.

Nature of projectile.	Number of dummies hit.			Effective shell.	
	Attacking line.	Supports.	Main body.	Number.	Hits per shell.
Boxer-shrapnel, time fuze.....	53	4	0	18	3·17
" percussion fuze ...	19	1	1	16	1·31
Water shell, " ...	17	1	1	12	1·58
Common shell, " ...	7	1	0	13	0·62

15. A similar experiment (Series E) at the same targets, but at a range of 2100 yds., was carried out on the 11th August, with the following results :—

9-pr. R.M.L. Gun, 6 cwt., R.H.A.

Nature of projectile.	Number of dummies hit.			Effective shell.	
	Attacking line.	Supports.	Main body.	Number.	Hits per shell.
Boxer-shrapnel, time fuze.....	33	0	0	17	1·94
" percussion fuze ...	18	3	0	17	1·24
Water shell, " ...	14	2	0	14	1·14
Common shell, " ...	4	0	0	5	0·80

* In ascertaining the range, the Committee used Nolan's range-finder only.

16-pr. R.M.L. Gun, 12 cwt., R.A.

Nature of projectile.	Number of dummies hit.			Effective shell.	
	Attacking line.	Supports.	Main body.	Number.	Hits per shell.
Boxer-shrapnel, time fuze.....	37	0	0	14	2·64
" percussion fuze ...	14	0	0	17	0·82
Water shell, " ...	8	0	0	11	0·73
Common shell, " ...	9	0	0	17	0·53

In these tables the order of merit is modified by taking the number of effective shells into consideration. The water shell in the table immediately above, which disabled 8 dummies with 11 effective shell, takes precedence of the common shell, which with 17 effective rounds disabled only 9.

16. On the 13th August, a comparison between the four projectiles was afforded by deliberate practice at a range of 3000 yds. against Target No. 3. This consisted of a half-battalion of wooden dummies in company quarter column, with double interval between the files, two paces between the ranks, and six paces between the companies.

The front of the column was 80 yds., and its depth 26 yds. The guns came into action on Moorgate Down, nearly on a level with the target, which was on the north slope of a hill called Yes Tor, the right flank of the advancing column being higher than the left.

The 9-pr. battery fired 18 rounds of each of the four natures of projectiles with the following result:—

9-pr. R.M.L. Gun, 6 cwt., R.H.A. Range 3000 yds.

Nature of projectile.	Number of dummies hit.					Effective shell.	
	No. 1 Comp.	No. 2 Comp.	No. 3 Comp.	No. 4 Comp.	Total.	No.	Hits per shell.
Boxer-shrapnel, time fuze.....	18	23	24	7	72	17	4·23
" percussion fuze ...	4	9	7	2	22	16	1·37
Water shell, " ...	8	9	18	12	47	7	6·71
Common shell, " ...	3	6	2	4	15	7	2·14

The 16-pr. battery fired the same number of rounds, 18, of each nature of projectile, except of common shell, of which 24 rounds were fired. The following was the result:—

16-pr. R.M.L. Gun, 12 cwt., R.A. Range 3000 yds.

Nature of projectile.	Number of dummies hit.					Effective shell.	
	No. 1 Comp.	No. 2 Comp.	No. 3 Comp.	No. 4 Comp.	Total.	No.	Hits per shell.
Boxer-shrapnel, time fuze.....	32	22	33	22	109	17	6·41
" percussion fuze ...	20	23	26	15	84	18	4·66
Water shell, " ...	7	17	15	43	82	12	6·83
Common shell, " ...	10	13	9	14	46	12	3·83

17. On the 21st August, practice was carried on with all four projectiles at a range of 1500 yds. against Target No. 5. This was a 16-pr. M.L. gun in action, with a detachment of 8 dummies, and two 6-ft. targets in rear of the trail to represent the limber and horses. Eight rounds of each description of projectile were fired, with the following result:—

16-*pr. R.M.L. Gun,* 12 *cwt., R.A., at Target No.* 5. *Range* 1500 *yds.*

Nature of projectile.	Number of dummies hit.	Number of hits on limber targets.	Number of hits on gun and carriage.	Effective shell.	
				No.	Hits per shell.
Boxer-shrapnel, time fuze.....	8	36	32	8	9·50
" percussion fuze ...	2	2	0	7	0·57
Water shell, " ...	6	37	1	5	8·80
Common shell, " ...	2	2	1	4	1·25

18. On the 23rd August, another opportunity was afforded of comparing the four projectiles by practice from the 16-pr. battery at a range of 2030 yds. against a 16-pr. gun in action, with a detachment of dummies (the whole sheltered in a hastily constructed gun-pit, and constituting Target No. 6.) The battery was in action on Holstock Hill, and fired 12 rounds of each description of projectile, with the following result:—

16-*pr. R.M.L. Gun,* 12 *cwt., R.A., against Target No.* 6. *Range* 2030 *yds.*

Nature of projectile.	Hits on work.	Number of dummies disabled.	Remarks.	Number of effective shell.
Boxer-shrapnel, time fuze.....	0	6	Wheels of carriage much injured; many grazes of bullets on gun and carriage; pit full of shell fragments.	10
Boxer-shrapnel, percussion fuze ...	2	1	—	11
Water shell, " ...	1	1	—	6
Common shell, " ...	1	0	—	5

19. On the same date, practice was made by the 16-pr. battery, at a range of 2075 yds., against two guns (at intervals of 19 yds.) in the open, with targets to represent limbers and horses, in rear of the gun. As, however, the target was not examined between each series of projectiles, no strict comparison can be drawn.

20. On the same date, in the course of another experiment, the four natures of projectile were also fired against Target No. 7, a hasty trench containing 46 kneeling dummies. Six rounds of each were fired, at two ranges; but an approximate result only can be formed, as the targets at the shorter range were not examined after each 6 rounds, but after each 12. The following gives the result of the firing, the battery being situated so that the line of fire was at an angle of 35° with the front of the trench.

9-*pr. R.M.L. Gun*, 6 *cwt.*, *R.H.A.* *Range* 1455 *yds.*

Nature of projectile.	Number of dummies disabled.	Effective shell.	
		Number.	Hits per shell.
6 rounds common shell and 6 rounds water shell, percussion fuze.	14 (Trench struck also in two places).	8	1·75
6 rounds Boxer-shrapnel with time fuze, and 6 rounds Boxer-shrapnel with percussion fuze.	10	12	0·83

21. An experiment—to be alluded to hereafter under class III.—was carried out on the 26th August, and afforded a comparison between the effects of water shell with percussion fuze and Boxer-shrapnel, both with time fuze and with percussion fuze—the target being half a battalion of dummies, in attacking order, the first line consisting of 103 kneeling in very open order and taking advantage of every cover, many of them being quite concealed behind rocks, and the second and third lines lying down, and being at about 50 yds. distance from one another. The same distance existed between the first and second lines. The result was as follows:—

16-*pr. R.M.L. Gun*, 12 *cwt.*, *R.A.* *Range* 1950 *yds.*

No. of rounds	Nature of projectile.	Number of dummies hit.			Effective shell.	
		1st line.	2nd line.	3rd line.	Number.	Hits per shell.
36	Boxer-shrapnel, percussion fuze ...	35	1	1	36	1·03
35	Water shell, percussion fuze	30	0	1	25	1·24
36	Boxer-shrapnel, time fuze	44	5	1	36*	1·39

* Including some shell which burst on plane.

22. On the 30th August and 1st September, practice was carried on to ascertain the comparative effect of a considerable number of shrapnel shells with time fuzes, and the same with percussion fuzes, and water shells, fired rapidly. The target (No. 4) represented a regiment of cavalry in quarter-distance column of squadrons. The following was the result:—

16-*pr. R.M.L. Gun*, 12 *cwt.*, *R.A.* *Range* 2000 *yds.*

No. of rounds.	Nature of projectile.	No. of hits.	No. of troopers disabled.	Effective shell.	
				Number.	Hits per shell.
36	Boxer-shrapnel, time fuze	1512	182	29	52·14
36	" percussion fuze ...	1574	131	36	43·72
36	Water shell, " ...	3892	186	33	117·94

The great discrepancy in the table between the number of hits and the number of troopers disabled is due to the following cause. In the operation of examining the targets, *facsimiles* of the original are made on a small scale, reproducing the exact position of the hits. A plate of glass on which the figures of troopers are traced is then placed over the drawing, and any hits which fall *without* the figures are not counted. Further, one trooper may be hit twenty times, but he only counts as one.

23. On the 20th and 30th August, further experiments were tried with the following results, at greater ranges, and offering further means of comparison.

The practice referred to in the two following tables was carried on by salvos, the distance, as measured by Nolan's range-finder, being communicated to the officer commanding the battery.

9-pr. R.M.L. Gun, 6 cwt., R.H.A. Range 3500 yds.

No. of rounds.	Nature of projectile.	No. of hits.	No. of troopers disabled.	Effective shell.	
				Number.	Hits per shell.
Salvo.					
6	Boxer-shrapnel, time fuze.....	233	60	4	58·25
6	" percussion fuze ...	38	13	Not observed.	—
6*	Water shell, " ...	0	0	0	—
6	Common shell, " ...	58	27	6	9·67

* All the shells fell beyond the target.

16-pr. R.M.L. Gun, 12 cwt., R.A. Range about 4000 yds.

No. of rounds.	Nature of projectile.	No. of hits.	No. of troopers disabled.	Effective shell.	
				Number.	Hits per shell.
Salvo.		Salvo.			
6	Boxer-shrapnel, time fuze.....	80	8	3*	26·67
6	" percussion fuze ...	140	25	5	28·00
6	Water shell, " ...	48	11	3	16·00
6	Common shell, " ...	6	1	3	2·00

* Burst on plane, fuzes being too long.

On the 20th August the range was 3956 yds. to the centre of column, for the 16-pr., but on the 30th the target was moved 40 yds. further back. The practice referred to in the above tables was carried on by *salvos* at a known range; the following results were from independent and deliberate firing at the same targets.

9-pr. R.M.L. Gun, 6 cwt., R.H.A. Range 3500 yds.

No. of rounds.	Nature of projectile.	No. of hits.	No. of troopers disabled.
12	Water shell, percussion fuze.....	331	49
12	Boxer-shrapnel, "	166	22
12	Common shell, "	42	20

16-pr. R.M.L. Gun, 12 cwt., R.A. Range about 4000 yds.

No. of rounds.	Nature of projectile.	No. of hits.	No. of troopers disabled.
12	Water shell, percussion fuze.....	165	34
12	Boxer-shrapnel, "	189	23
12	" time fuze.....	100	17
12	Common shell, percussion fuze.....	7	3

24. One other experiment, which afforded a comparison between shrapnel with percussion fuzes and water shell, although carried on for other purposes, may here be mentioned. The target, No. 2, was composed of dummies, and a fixed number of rounds was fired at the attacking line, supports, and main body, from distances varying from 1600 to 3125 yds. Twelve rounds of each projectile were fired at the attacking line and supports, and twenty-four at the main body. The following is a summary of the results, which will be found in detail elsewhere:—

9-pr. R.M.L. Gun, 6 cwt., R.H.A. Ranges from 1600 to 3125 yds.

No. of rounds.	Nature of projectile.	Number of dummies disabled.			Effective shell.	
		1st line.	2nd line.	Main body.	Number.	Hits per shell.
48	Boxer-shrapnel, percussion fuze..	11	8	9	34	0·81
48	Water shell, " ...	7	19	53	28	2·08

(Class I.) Conclusions.

25. The Committee are unanimous in thinking that both time and percussion shells are indispensable to the efficiency of the field artillery. Both have their *rôle*.

The destructive effect of a good time shrapnel against troops in any loose formation, and presumably in motion, must, in their opinion, be greater than that of a shell burst on graze.

Against column formations, when the range is known, both natures appear to be equally efficient.

The time shell has the advantage when firing at batteries or troops retired behind the crest of a hill.

The effect, however, of time shrapnel, depends greatly on the accuracy with which, when firing at objects in motion, the varying distances are estimated; the care and judgment in boring the fuzes to correspond with these conditions; and the capability of observing the value of each shell, as regards height and distance of the point of burst from the object.

On the other hand, the extreme simplicity of the service of percussion shells, and the valuable aid they offered in readily picking up and varying the range, are advantages that cannot be over-estimated, and render a projectile of this nature especially valuable for use in the excitement and heat of action.

The chief disadvantage in the employment of percussion shells arises from the uncertainty due to the nature and formation of the ground on which the shell may graze, and the possibility of its proper action being altogether nullified or seriously interfered with.

Moreover, the limit of error is much greater with a time than with a percussion shell; the former being effective at ordinary ranges if burst within 150, or even, in the case of the 16-pr., 200 yds. of the front of a body of troops, whereas the latter must burst either within a short distance of the front of an object, or on the head of a column, to ensure proper effect.

As regards the value of the different projectiles under trial at Okehampton, the Committee consider—

Time Shrapnel.—1st. That boxer-shrapnel, as a time shell, may be considered as thoroughly efficient.

Percussion Shrapnel.—2nd. Boxer-shrapnel, being designed specially for bursting in the air, is not calculated to afford the best results as a percussion shell; in fact, its use as such is opposed to the principle on which it is constructed.

Still, the results of the Okehampton experiments shew that these projectiles, when burst under proper conditions, are very destructive, and that they may be safely relied on until some other percussion shell, less expensive and equally efficient, has been produced.

It will be observed by the Reports that a small percentage of these shells, notwithstanding every care taken in the manufacture, still break up prematurely, but the number has apparently been reduced to a minimum, and as the defect is likewise observable in the common shell, which is of much stronger construction, the Committee fear that the occasional breaking up of a shell must, at present, be accepted as one of those contingencies against which it is impossible at all times to guard.

Nature of shell.	9-pounder.		16-pounder.	
	Number fired.	Premature.	Number fired.	Premature.
Shrapnel	680	1	565	2
Common	84	1	154	3
Water	132	0	200	2

Water Shell.—The Committee are of opinion that the water shell, as used by them at Okehampton, is capable of producing a greater effect against troops, as a percussion shell, than any projectile with which they are acquainted.

It possesses the advantage of extreme simplicity and cheapness, it being only necessary to fill the common shell with water, and fit it with a small cylinder containing gun-cotton and detonating fuze, to render it suitable for use on graze.

Owing, however, to the absence of a puff of smoke on bursting, it is difficult to mark the spot where the shell grazes, and one of the advantages of a percussion shell is thus lost.

Further, it has yet to be proved whether the detonator and dry gun-cotton primer will successfully withstand the effects of climate and travelling.

The Committee have, in conjunction with the Superintendent Royal Laboratory and Chemist War Department, taken steps to ascertain whether the first objection—namely, the absence of a puff of smoke, can be obviated, and if the results are successful they will recommend that a proportion of detonators and primers be issued to field batteries, both at home and abroad, for trial.

Common Shell.—The field service common shell, with its ordinary charge of powder, has proved throughout these experiments to be ill adapted for use against troops, and the Committee recommend that the proportion carried by field batteries be revised, a certain number being retained for firing into villages, stockades, woods, or against obstructions of any kind.

Fuzes.—The Boxer wood time fuzes (5 secs. and 9 secs.) used during the experiments, maintained their high character of efficiency, but the Committee are of opinion that improvements are possible in the graduation of these fuzes, and that one pattern might take the place of both.

The R.L. percussion fuze acted well throughout the whole of the trials, although the ground was generally unfavourable for percussion shells. It is the safest and most efficient percussion fuze for field service with which the Committee are acquainted.

(Class II.) The Effective Zone of Artillery Fire.

26. The Committee having proved by former experiments the accuracy of the shooting of both 9-pr. and 16-pr. guns for ranges exceeding the effective range laid down in rules approved for the Umpire Staff at the Aldershot Manœuvres of 1875—namely, 2000 for 9-prs. and 2500 for 16-prs.—went further, and carried on successful practice with the 9-pr. gun up to 3500 yds., and with the 16-pr. at various ranges up to 4000 yds.; and by means of the co-operation of the Superintendent of the Royal Laboratory they were enabled to burst shrapnel shell by special time fuzes up to 4000 yds.

The results of the practice at various ranges may be summarized as follows:—At 2000 yds. the 16-pr. battery fired in 9 minutes 36 rounds of water shell at Target No. 4, and made 3892 hits; it fired the same number of rounds of shrapnel (percussion) in 5 minutes, making 1574 hits. On another occasion, at the same range and target, the 16-pr. battery fired in 10 minutes 36 rounds of shrapnel with time fuze, and made 1512 hits.

At 2030 yds., the same battery with 12 rounds of shrapnel, with time fuze, disabled every one of the detachment of a gun sheltered in a gun pit, besides injuring the carriage.

At 2100 yds., with 72 rounds of various projectiles fired deliberately, the 9-pr. battery hit 69 out of 100 dummies in an attacking line at open intervals, while the 16-pr. hit 68.

On the 18th August, with shrapnel and time fuzes, the ranges being found by Nolan's range-finder, the following results were obtained:—The 9-pr. battery, with 12 rounds at a range of 2575 yds., in 4 minutes hit 12 dummies out of 100 in extended order, and with 24 rounds at ranges of 2250 and 1625 yds. hit 40 dummies out of a similar body of 200 in 8½ minutes. On the same occasion, and with the same projectile, the 16-pr. battery in 7 minutes hit 26 dummies out of 200 in open order, at a range of 2600 yds. in 12 rounds, and at a range of 3120 yds. at the same target hit 20 dummies in 8½ minutes.

On the 13th August, at a range of 3000 yds., firing deliberately at a column of infantry of four companies with double interval between the files and six paces between the companies, the 9-pr. battery, with 72 rounds of various projectiles, hit 156 dummies out of 400, while the 16-pr. battery, under the same circumstances, hit 321.

At a range of 3500 yds., firing at No. 4 Target mentioned above, the 9-pr. battery with 6 rounds (salvo) of shrapnel with time fuze made 233 hits, and with 12 rounds—2 per gun, independently and rapidly—of water shell at the same range made 331 hits.

At a range of 4000 yds., firing at the same target, the 16-pr. battery with 6 rounds (salvo) of shrapnel with percussion fuze made 140 hits, with 12 rounds of shrapnel with time fuze, fired independently and rapidly, made 100 hits, with 12 rounds of water shell made 165 hits, and with 12 rounds of percussion shrapnel made 189 hits.

On the 30th of August, at a range of 5200 yds. as given by Nolan's range-finder, the 16-pr. battery, in a bad light, without proper tangent scale, and firing up a considerable angle, placed either in the Target No. 16, or within 25 yds. of it, 13 out of 18 common shell. Had the target been a farm steading, or a group of cottages, the result would have been satisfactory.

(Class II.) Conclusion.

The Committee are of opinion that bodies of troops cannot with impunity remain stationary, or even move deliberately in front of guns, at any distance under 4000 yds., if the ground is at all open, the artillery posted so that they can see that distance, and the atmosphere clear. Villages or depôts of stores would be unsafe at longer ranges.

(Class III.) The Value of Artillery Fire against the most recent Formations of Infantry.

27. In carrying out the experiments to ascertain the results of artillery fire against recent infantry formations, and the nature of projectile which, under different conditions, will produce the *maximum* effect, the Committee

as far as possible followed the instructions conveyed in the memorandum on "Formations for Attack on the Half-battalion System," which accompanied General Orders No. 23 of 1873.

The rules for conducting the attack of a division are there laid down, and may briefly be stated as follows:—

The attack will commence with a general advance, and assuming the division to consist of two brigades, one brigade will be formed in front of the other in the formation for attack, while the other brigade, in line of, say, half-battalion quarter-columns of companies, will be in reserve, if possible under cover, about 500 yds. in rear.

The brigade attacking on the half-battalion system will advance in, say, line of half-battalion quarter-columns of companies at deploying intervals, and on finding itself under the fire of artillery, will either deploy or break into the attacking formation.

In the latter, two half-battalions of the same battalion, taken from either flanks or centre, will cover the front of the brigade, each with skirmishers and supports.

This attacking formation is represented in Targets Nos. 2 and 10, where an attacking line in rank entire, with one pace between each man, is followed at about 250 paces by a supporting line in double rank, at open interval; the supports being, in their turn, followed at about 350 paces by the main body, in company quarter-column at double interval.

When the attacking line comes within infantry range of the enemy, it virtually becomes a line of skirmishers, to be fed by the supports, which in turn are fed by the main body and reserves.

The effect of artillery fire against a formation of this character may be considered under two aspects—

1st.—The distance at which an enemy would be compelled to break into a looser formation than column.

2nd.—The effect of artillery fire upon this looser formation.

The first step taken by an army in masses, finding itself unexpectedly under artillery fire at long ranges, and yet unwilling to injure its powers of rapid and concentrated locomotion, or unable to obtain adequate cover, would be probably to open out its columns. In the experiments of the 13th August this was assumed, and, with 18 rounds of shrapnel with time fuze, at a range of 3000 yds., four 16-pr. guns in 11 minutes disabled 109 out of 400 dummies, drawn up in company quarter-column at open intervals, and with six paces between the companies. With a total of 72 rounds of various projectiles, it disabled 321 out of 400.

Under a fire so effective as this, the columns pressing on in rear would be compelled to adopt another formation, and would probably advance somewhat as shewn in Target No. 2. This formation is, in many respects, a very favourable one. Fire directed against the first or attacking line produced virtually no effect against the supports or main body. The distances were such as to render the *ricochet* of fragments harmless, and therefore, if the fire were directed against the attacking line alone, the general advance of the main body would not be impeded.

28. On the 18th August, a rapid fire against the attacking line, the

supports, and the main body, *ensemble*, was tried and was successful. The Target No 2 represented half a battalion of 400 men, disposed as follows:—Attacking line, one company in rank entire, one pace between the men; at 250 paces, a supporting line, one company with open files—*i.e.*, two paces interval, in line; at 350 paces from supports, the main body, two companies in company quarter-column at double interval. The fire was carried on, 12 rounds at a time, at different parts of the column, and the target examined at each pause. The batteries changed their position after every 12 rounds. The following was the result:—

9-pr. R.M.L. Gun, 6 cwt., R.H.A. Target No. 2.

No. of rounds.	Time.	Nature of projectile.	Part of column aimed at.	No. of effective rounds.	No. of dummies disabled.
	minutes.				
12	2	Shrapnel, with time fuze.	Attacking line.	7, but 2 of them burst on plane.	18
12	4½	Do.	Supporting line.	2	12
12 } 12 }	8½	Do.	Main body.	8	40
48	—	—	—	17	70

16-pr. R.M.L. Gun, 12 cwt., R.A. Target No. 2.

No. of rounds.	Time.	Nature of projectile.	Part of column aimed at.	No. of effective rounds.	No. of dummies disabled.
	minutes.				
12	5	Shrapnel, with time fuze.	Attacking line.	11, but 3 of them burst on plane.	21
12	6	Do.	Supporting line.	11, but 3 of them burst on plane, and 1 was very short.	21
12 } 12 }	15½	Do.	Main body.	18, but 3 of them burst on plane.	46
48	—	—	—	40	88

29. On the 26th August, the 16-pr. battery came into action against the following target, at a range of 1950 yds. A half-battalion of dummies was represented in attacking order, on rough ground, affording every facility for cover. The first line consisted of 103 short dummies, cut down to the height of a kneeling man. These were placed impartially behind any cover which presented itself, without diverging too much from the direct line of attack. Some were completely hidden by rocks. The second line was about 50 yds. in rear of the first, and the third about 50 yds. in rear of the second. These two lines were represented by dummies lying down, supposed to be in the interval between two rushes, and virtually offering no object at which to aim. Under the conditions, as mentioned under Class I., with 36 rounds of

Sig 70 Missing

Number of rounds fired.	Number of rounds fired before ascertaining the range.	Battery.
12	4	"E" Battery, "E" Brigade, R.H.A.
12	3	" " "
12	3	" " "
12	1	"C" Battery, 25th Brigade, R.A.
12	5	" " "
12	6	" " "
12	3	" " "
12	7	"E" Battery, "E" Brigade, R.H.A.
Total...96	32	

The officers and men had never been systematically practised in judging distances on land ranges by trial shots.

47. On the 25th August, an experiment was tried with the view of comparing the results of practice without a range-finder, and with a range-finder, both on tripods and on the guns. The battery was kept constantly moving: the targets were composed each of a section of 12 files at open order, one pace interval between the files; and the projectile was shrapnel with percussion fuze—a projectile for which both ground and target were unfavourable. The following was the result, as to range and effect:—

9-*pr. R.M.L. Gun*, 6 *cwt.*, *R.H.A.*, *August* 25*th*, 1875.

Nature of practice.	Number of rounds fired.	Number of rounds before getting range.	Number of dummies disabled.
Without range-finder	12	8	3
" "	12	6	7
" "	12	0	19
" "	12	0	24
With range-finder on gun	12	0	18
" " "	12	3	8
" " on tripods...	12	1	7
" " " ...	12	3	15
" " " ...	12	1	12
" " " ...	12	0	22

NOTE.—With so small a target the range in the above table has been considered as ascertained when the projectile grazed within 10 yards of it.

(CLASS V.) CONCLUSIONS.

48. The Committee propose to associate the question of range-finders with other points which are of no less importance, and on which the value of rifled artillery materially depends.

In equipment the Royal Artillery may fairly claim to be equal to that of any other nation; but, judging from their knowledge of the regiment and experiments at Okehampton, it is evident to the Committee that there is very great room for improvement in systematic and accurate shooting and in judging distance.

The introduction of Nolan's range-finder will certainly supply a great want. It is especially valuable at ranges exceeding 2000 yds., as without

it, at these distances, much time and ammunition are wasted. But there are occasions when the range-finder is not likely to be used at all. For example, in coming suddenly and rapidly into action at comparatively short ranges, to check the advance of troops moving quickly, and perhaps *across* the front; or, with horse artillery advancing with cavalry, to give a finishing blow to a wavering body of troops; or in actively pursuing a retiring enemy at constantly changing distances. These are three instances when the range-finder would not, in all probability, be employed. But its use would nevertheless be very desirable on many occasions—all the more since the increased ranges of field artillery minimise the movements of batteries, and allow a certain amount of deliberation and opportunity for taking the range of prominent points within the zone of fire. The range-finder would also be a valuable aid in teaching the judging of distances, up to 2,000 yds., as, by checking the estimates formed, it would gradually educate the eye. For these reasons the Committee concur with the Special Committee in recommending the issue of a range-finding instrument to every battery, the instruments being used on tripods instead of on guns; but, at the same time, they wish to state that this recommendation is contingent on the recognition by the authorities of the absolute necessity of maintaining a thoroughly well-organised establishment of trained men and horses for the proper care and use of these instruments. The Committee are confident that if this be not done, the strain on the establishment of a battery which will be caused by drawing from it men and horses for range-finding duties will be such as to make the work distasteful, and lead to its being imperfectly performed.

The Committee cannot too strongly urge the importance of making the annual practice of batteries more a trial of skill in accuracy of shooting than it is at present. The introduction of Nolan's range-finder will be a step in this direction; but more would be done by introducing some system of field artillery gun practice, such as exists in Germany and Austria, and is described in "R.A. Institution Papers," No. 1, Vol. VIII., "Translations." The great drawback now is the use of *sea*-ranges, over which the annual practice of batteries is to a very great extent carried on, and which give an unreality to the fire and use of field artillery. This unreality—this difference from the conditions of service—diminishes the interest in the practice, and by absence of adequate results leads to a wasteful expenditure of ammunition. The use of *land* ranges, as was emphatically shewn at Okehampton, would also admit of valuable instruction and practice in driving. The Committee therefore trust that every effort will be made to secure suitable *land* ranges in different parts of the United Kingdom, where batteries could be assembled and practice carried on in a way approaching to the conditions of actual service. The greater part of the annual allowance of ammunition should be expended at targets placed at a variety of unknown distances, the position of the battery being changed as soon as the range is found. The value and importance of every single round of ammunition should be strongly impressed on the young soldier. The Committee would also recommend (with reference more especially to the recent mobilization scheme) that occasionally, as in India, batteries should be conveyed to the practice-grounds by rail, to give officers and men an idea of the method of conveyance which would be employed in the event of the rapid concentration of an army corps.

There is another means of improving the accuracy of artillery shooting,

which would do nearly as much service as the range-finder or the use of land-ranges. The Committee would beg to point out that the artillery is the only arm of the service in which there is no organised system of rewarding men for excellence in shooting or in driving. In the artillery alone is there no annual publication of the results of the year's practice, to excite a wholesome emulation between batteries. Even the Volunteer Artillery have the advantage of prizes, to stimulate the men to the study of their profession. In the cavalry and infantry there are both badges and money prizes to reward proficiency in the use of arms: in the artillery there is no such advantage. Many schemes have been proposed to meet this want—one especially, published at the R.A. Institution by Captain T. B. Strange, in 1870—and the Committee are unanimous in recommending the extension to the artillery of the system which exists in the rest of the army.

RECOMMENDATIONS.

49. (1) Pending further experiments with the "water shell," the Committee recommend that the proportion of projectiles carried by field artillery per gun and wagon be as follows:—

	9-pr.	16-pr.
Shrapnel shell	112	76
Common shell	28	20
Case shot	4	4

The shrapnel shells to be used with time fuzes when required to burst in the air, and with percussion fuzes when intended to act as percussion shells on graze. The common shells to be used with either time or percussion fuzes, according to the nature of the service required. Steps should be taken to ascertain whether the common shell could not be made more of an incendiary projectile by the addition of some carcass composition or other combustible substance to the present bursting charge.

In the event of the failure of the water shell, efforts should not be relaxed to obtain a cheaper and more efficient percussion shell than Boxer-shrapnel. (See para. 25.)

(2) The present proportions of 5-seconds and 9-seconds wood time fuzes should, in the opinion of the Committee, be reversed, as the effects of time shrapnel have been shown to be considerable at ranges over 1700 yds., which is the limit of the 5-seconds fuze. The proportions carried with the 16-pr. should correspond to those of the 9-pr.

(3) Experiments should be instituted to ascertain whether a wood time fuze cannot be constructed to suit longer ranges than the present 9-seconds fuze, and at the same time, by a different graduation, obtain greater nicety of action. Such a fuze might supply the place of both the 5-seconds and 9-seconds fuzes.

The Committee have taken steps to procure an improved hook-borer for time fuzes.

(4) The clinometer now issued to batteries is, in the opinion of the Committee, inadequate and out of date, and they recommend the introduction

of a better form of quadrant, which could be used not only for giving high elevations, but for correcting the height of wheels, when firing deliberately at long ranges.

(5) The sponge-staves of field guns should be marked to shew when the shell is home when using the service charge.

(6) The Committee think it advisable that the spare gun-carriage should form part of the equipment of a battery as formerly, owing to the possibility of a carriage receiving damage which could not be repaired in the field.

(7) The present field artillery carriages should be strengthened in those parts which shewed weakness during the experiments. The Committee have already taken steps in this direction.

(8) With respect to the suitability of the present mode of packing stores, with reference to facility of supply of ammunition to guns in action, the Committee think that endeavours should be made to dispense with the present centre box. They think it possible that two limber ammunition boxes might be constructed to take the place of the three boxes now carried.

(9) The Committee concur with the Special Committee on Range-Finders that a set of Nolan's small-pattern field instruments be issued to every field battery; but they strongly urge the necessity of making "range-finding" a special instruction and duty. Unless the establishment of a battery be increased by three men and three horses, the Committee do not think range-finding duties could be efficiently performed. (See para. 48.)

(10) The Committee strongly urge that the conditions under which the annual practice of batteries is carried out be revised, and that endeavours be made to procure several land-ranges in different parts of the United Kingdom, where two or more batteries at a time could be encamped for practice. From their experience of Okehampton, the Committee think that, as a commencement, it is most important and desirable to establish a standing camp there for instruction during the summer months. (See para. 48.)

(11) The square targets used for experimental purposes are very cumbrous, heavy, and expensive, and the Committee think a much lighter and cheaper target might be used for annual practice. Suitable targets for this purpose might be obtained in most places.

(12) The Committee strongly urge the introduction of some system of rewarding excellence in artillery practice analogous to that existing in the rest of the army. (See para. 48.)

(13) The Committee consider that the allowance of practice ammunition per field battery might be judiciously increased. The present allowance (200 rounds) is considerably less than that issued for this purpose in foreign armies—notably in the case of the German artillery.

(14) The Committee recommend that every field battery proceeding on service should take a good telescope, with tripod stand, as part of its equipment, and they suggest that steps be taken to procure a suitable pattern, which must be strong, simple, and powerful.

(15) The necessary alterations should be made in the fuze-scale graduations of the range-plates and tangent-scales of 9-pr. rifled M.L. guns of 6 cwt.

14th February, 1876.

APPENDIX.

Description of Projectiles used at Okehampton.

Boxer-Shrapnel Shell.—The shrapnel shell for 16-pr. guns was that known as Experimental, pattern E.

It was filled with 72 mixed metal bullets at 18 to the pound, 56 bullets at 84 to the pound, and 1½-oz. bursting charge.

The walls of the cast-iron shell were 0·45 ins. thick, and there were no interior longitudinal grooves. Mean weight, 18 lbs. 6 ozs.

The 9-pr. shrapnel shell was Mark V. pattern.

It was filled with 63 mixed metal bullets at 18 to the pound, 35 at 34 to the pound, and 12 drams bursting charge. Mean weight, 9 lbs. 13 ozs.

Common Shell.—The ordinary service common shell was used with both guns.

16-pr. filled with 1 lb. of powder. Mean weight, 15 lb. 13 ozs.

9-pr. filled with 7½ ozs. of powder. Mean weight, 9 lb. 1 oz.

Water Shell.—The ordinary common shell is converted into a "water shell" by filling it with water instead of gunpowder, and inserting a small gunmetal cylinder, containing the explosive, into the fuze-hole in addition to the R.L. percussion fuze. It was proposed by F. A. Abel, Esq., F.R.S., the Chemist of the War Department.

In the water shells used at Okehampton, the small gunmetal cylinder was about 2·2 ins. in length, by 0·8-in. internal diameter. It contained, in the body, three pellets of dry compressed gun-cotton, protected by a coating of paraffin, and weighing together about one-third of an ounce, called the primer. Its top was fitted with a removable gunmetal chamber, which contained about 20 grains of fulminating mercury.

This gun-metal chamber, called the "detonator," can be removed and replaced by a solid plug, if necessary, for safety during transit or storage.

The shell was filled as follows:—

> The plug was removed, and water was poured into the interior until it rose into the bottom of the fuze-hole. The gunmetal cylinder, containing the "primer" and "detonator," was then screwed home in the fuze-hole as far as it would go, the plug was then replaced. When required for use, the plug was removed and the R.L. percussion fuze screwed into the shell.

The action of the shell is as follows:—

> On striking the ground, or any object, the percussion fuze acts and fires the fulminating mixture, which detonates the gun-cotton. The force of the explosion, acting through the incompressible substance water, is then instantaneously and completely transmitted in all directions, and the shell is thus broken up into a far greater number of pieces than that obtained by employing the full charge of gunpowder which it can contain.

Description of the M.L. Wood Time Fuze, Experimental, supplied to Okehampton.

The external dimensions of the 15-secs., 10-secs., and 5-secs. fuzes are the same as the 10-secs. and 5-secs. service fuzes, the composition bore being concentric,

each having four rows of side holes and channels. The side holes are so arranged that the fuze can be bored to burn at intervals as follows, viz.:—

15-secs. to $\frac{1}{2}$ seconds.
10 " " $\frac{1}{4}$ "
5 " " $\frac{1}{8}$ "

They are matched, primed, and finished, same as the ordinary M.L. fuzes, and externally painted as follows:—

15-secs., white body and black head.
10 " black " " white "
5 " all *red.*

Composition.

	15″. lbs.	ozs.		10″. lbs.	oz.	5″.
Saltpetre	3	4	...	3	4	Powder.
Sulphur	1	0	...	1	0	"
Powder	2	0	...	2	12	"

Forwarded to Secretary, Rifled Field Gun Committee, by the Superintendent, Royal Laboratory, Woolwich, on 14th September, 1875.

Targets issued for the Experiments at Okehampton.

Targets, wood, 9′ × 9′ × 2″		150
" " 6′ × 6′ × 2″		40
Props, wood	$11\frac{1}{2}'$	300
	$8\frac{1}{2}'$	80
Dummies, Wood, men, with stays and pegs to suit	standing height, 1 in. thick	800
	kneeling " "	200
Carriages (with guns) wrought-iron, travelling, complete, but without limber, M.L.R.	16-pr.	1
	9-pr.	1

RESULTS OF EXPERIMENTS

MADE IN THE

ROYAL CARRIAGE DEPARTMENT,

(*in May and September*, 1876),

TO TEST THE RELATIVE STRENGTH OF DIFFERENT FORMS OF BRACKETS AND AXLETREES FOR FIELD GUN-CARRIAGES.

COMMUNICATED BY

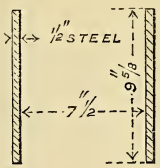
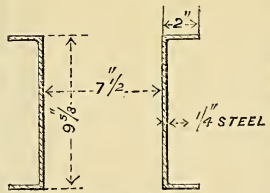
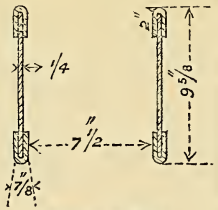
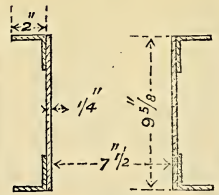
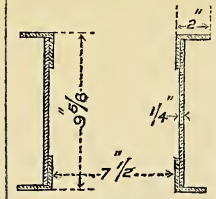
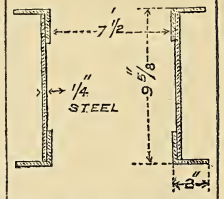
MAJOR W. KEMMIS, R.A.

I.—Brackets.

The specimens of brackets experimented upon were, approximately, of the same weight and dimensions; each consisted of two sides, of equal depth from end to end, 5′ 0″ long, connected by three collar bolts.

To test each specimen, it was supported with the sides vertical, their upper and under edges horizontal, upon two cast-iron blocks, 4′ 0″ apart; in which position a weight of 1134 lbs. was let fall, from a given height, upon a small wrought-iron block placed across the sides at the centre.

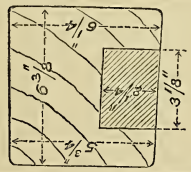
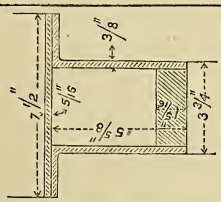
The particular section and weight of each bracket, together with the effect of the blows it received, are given in the following table:—

	A.	B.	C.	D.	E.	F.
	 Weight, 160 lbs.	 Weight, 117 lbs.	 Weight, 163 lbs.	 Weight, 168 lbs.	 Weight, 160 lbs.	 Weight, 170 lbs.
After 4 blows; one 2′ 0″ fall, three 1′ 6″ fall:—	ins.	ins.	ins.	ins.	ins.	ins.
Mean maximum vertical deflection	·350	·260	·237	·210	·125	·210
Mean maximum horizontal deflection.....	·255	·500	·365	·075	—	·155
Fracture	—	—	—	—	—	—
After 4 additional blows; 1′ 6″ fall:—						
Mean maximum vertical deflection	·650	·510	·365	·320	·355	·350
Mean maximum horizontal deflection.....	1·255	1·465	·875	·045	·100	·340
Fracture	—	—	—	—	—	—
After 2 additional blows; one 5′, one 6′ fall:—						
Mean maximum vertical deflection	1·665	1·210	1·850	1·075	1·235	1·175
Mean maximum horizontal deflection.....	6·350	1·755, and also in the opposite direction ·64.	3·000	·700	1·685	2·460
Fracture	—	—	—	Both plates fractured up 2¼″ from under edge, and at upper opened from angle-iron.	—	Upper angle-iron torn at centre, in direction of length.

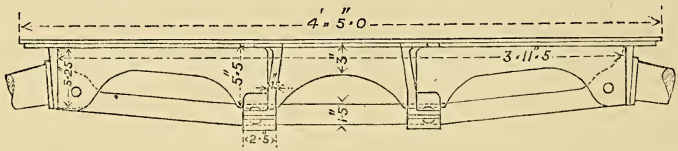
Specimen *A*, as might have been inferred from the disposition of the mass of the metal with regard to the neutral axis, shewed itself to be the weakest form, whether we regard vertical or horizontal strain. *B*, which is the form adopted in German field gun-carriages, stands next in weakness, being deficient in stiffness, and bending in all directions; it was, however, light in weight as compared with the other specimens. *C* shewed itself deficient in horizontal strength. *D*, *E*, and *F* proved the strongest forms, from the greater mass of metal in them remote from the neutral axes; *E* and *F* have the advantage over *D*, in the strain upon the rivets being relieved in them, and the liability of the plate tearing or cracking at the lower edge being reduced; the fracture of the upper angle-iron in *F* was due to it being compressed, locally, between the weight giving the blow and the hard steel plate beneath it—an action which could not take place in a gun-carriage.

II.—Axletrees.

The axletrees subjected to experiment were tested in the same manner as the specimens of brackets; the axletree arms were supported upon cast-iron blocks placed 4′ 1½″ apart, the upper surface of the axle-bed level, and the blow delivered by the falling weight (1134 lbs.) upon a wrought-iron block placed centrally across the top plate. The results obtained were as follows:—

	A.	B.	C.	D.	E.
					
	Weight, —	cwt. qr. lb. Weight, 2 0 4	cwt. qr. lb. Weight, 1 3 24	cwt. qr. lb. Weight, 1 3 25	cwt. qr. lb. Weight, 1 1 1½
		ins.	ins.	ins.	ins.
After 6 blows; 1′ 6″ fall:— Maximum vertical deflection	Not tried.	·30	·35	·20	·12
Fracture		—	One angle-iron slightly fractured at centre of under edge.	One angle-iron slightly fractured at centre of under edge.	—
After 5 additional blows; 1′ 9″ fall:— Maximum vertical deflection		·75	·67	·35	·26
Fracture		Axle and angle-iron fractured at centre.	The other angle-iron similarly fractured.	The other angle-iron similarly fractured.	—
After 7 additional blows; one 1′ 9″ fall, six 2′ 0″ fall:— Maximum vertical deflection		—	1·72	·75	·50
Fracture		—	Fracture of angle-iron increased, and slight crack in axle.	Fracture of angle-iron very slightly increased.	—
After 6 additional blows; 2′ 0″ fall:— Maximum vertical deflection		—	1·90	·87	·54
Fracture		—	Axle broken through 6¼″ from shoulder.	Fracture of angle-irons very slightly increased.	—

The specimens, *C*, and *D*, were constructed by simply replacing the service straight axle, as in *B*, by a round bent axle, between angle-irons already drilled for the former, and fitting packing pieces between the top plate and the axle at the positions of the brackets. The correct form of this axle and bed, as proposed by Mr. Butter, Manager R.C.D., is shown in the figure, in which there could be no tendency of the angle-irons to crack at the lower edges. This construction is far stronger



than that of *B*, in that it is of deeper section, while the axle is not weakened by rivet holes, and is subjected to a purely tensile strain; it is also, if damaged, much more easily replaced, being secured by a few instead of many rivets, and being of small section, if broken, can be rewelded. The solid form, *E*, in steel, would, after slight damage, soon become unserviceable, and if broken could not be rewelded; it is also inconvenient for the attachment of axle seats, the necessary fittings for which would increase its weight considerably. In a comparison of strength to withstand statical pressure, made between the forms *A*, and *B*, it was found that while the breaking strain of the former was $22\frac{1}{4}$ tons, that of the latter was $54\frac{3}{4}$ tons.

Royal Arsenal,

October 1876.

PRÉCIS OF THE FRANCO-GERMAN WAR.

BY

CAPTAIN S. C. PRATT, R.A.

Part III.

THE WAR IN THE PROVINCES. (SEPT. 1870 TO END OF WAR.)

General aspect of affairs.

The catastrophe of Sedan may be said to have terminated the first phase of the campaign of invasion, resulting as it did in the overthrow of the existing Imperial Government and the destruction of the sole regular French army in the field. The chances of a prolonged resistance seemed at this period almost hopeless, and the subsequent successful investment of Paris rendered matters still more desperate. Metz and Paris were surrounded by two powerful German armies, Strassburg was on the point of capitulating, the German reserves were pushing forward to occupy the conquered territory, and the broad zone of country extending from the Rhine to Paris was held by a million armed men. There were absolutely no regular French troops, a great scarcity of horses, and a complete dearth of warlike stores.

On the other hand, it might be fairly presumed that the capital was capable of holding out for a sufficient time to enable provincial levies to be raised in the more remote parts of the country. The army of Bazaine retained around it in its passive state a large proportion of the invading forces, and its active co-operation might, under certain contingencies, be looked for. The lines of German communications had already attained an inconvenient length, and along the whole of the southern portion of them the country was well adapted for defensive measures and partisan warfare.

In a rich and populous country, animated by a spirit of patriotism, it was an undoubted fact that large levies could be raised in a comparatively short time, but to what extent they would be able to make head against the regular troops of the invader was a matter of doubt. By attributing their disasters solely to treachery and political causes, the hopes of the nation had been raised, and were further influenced by eloquent descriptions of the successful general risings in 1793.

The Government of the National Defence proceeded to take immediate measures for the defence of the country, and in view of the impending investment of Paris, sent about the middle of September to Tours a number of authorised delegates, to the measures of whom a vigorous impulse was given by the subsequent addition of Gambetta—one of the

most energetic of the new *régime*. Men, *matériel*, and organisation were wanting; the cadres of officers had to be filled by many who had never served; and the whole staff and administrative services had to be extemporised. A small nucleus of regular troops was obtained by assembling the uncalled-out reserves, recruits from the various depôts, refugees from the frontier, and all the old soldiers in the country. Besides the Gardes Mobiles, a portion of the sedentary guard was mobilised, the formation of volunteer corps legalised, and after the surrender of Metz a general levy decreed of all able-bodied men without distinction between 20 and 40 years of age. By means of these stringent measures nearly 700,000 men were raised, organised, and enabled to take an active part against the enemy during a period, from first to last, of about four months. By liberal contracts, formation of new arsenals, and a general appeal to the patriotism of the mercantile classes, the necessary supplies of guns, ammunition, clothing, and all warlike stores were speedily collected. To effect the more speedy instruction of the new levies, several camps were formed throughout the country—a useful measure which the rapid march of events did not permit of being fully taken advantage of. For the purposes of local defence the country was divided into four large commands in the north, west, centre, and eastern districts. As the available effective gradually increased, *corps d'armées* were assembled, and eventually grouped into the effective armies which played so conspicuous a part in the latter portion of the campaign. It must be remembered that the main object of all the provincial levies was to raise the siege of Paris; and to effect this, either directly or indirectly, every strategic movement was directed. Paris was France, and the extraordinary fictitious value placed upon the capital must not be lost sight of in considering the further military operations. Keeping in mind the springing up of armed levies in all parts of the empire, their natural assemblage as armies when sufficiently organised, and the ultimate object to which they all devoted themselves, will render more easy the task of connecting in one harmonious whole the several apparently distinct campaigns of the French Republic.

The war in the provinces, Sept.-Oct.

When the III. and IV. Armies were advancing against Paris, in the middle of September, the 4th Cavalry Division was detached southward, as a corps of observation, towards the Loire. Supported by a small force of infantry and artillery, it succeeded in reaching Pithiviers on the 23rd, after some slight skirmishing with Franc-Tireurs, but its progress was arrested at Toury a few days later by small bodies of regular troops. Early in October the advance from Orleans of troops of all arms forced the division to retire to Etampes. The German cavalry covering the west of the army of investment were at the same time sharply attacked near Maintenon, and it became evident that an advance of the enemy from the southern and western quarters might soon be expected. To protect the blockading army from the threatened blow, General Von der Tann was given command of the I. Bavarian Corps, the 22nd Division, and the 2nd and 4th Cavalry Divisions,* with orders to assume the offensive, and clear the country as far as the Loire. Advancing

Map 8.

* 38,000 men, 160 guns.

southwards, he came in contact with a French division at Artenay, and drove it back in disorder. Following up his success, the advance was 10th Oct.
continued the next day, and a portion of the newly-formed 15th French Corps attacked in a rear guard position it had taken up to the north of Orleans. The elements of the future Army of the Loire were much scattered at this period, and the French forces, unable to hold their ground, fell back, after a stubborn resistance, through the city, which was occupied the same night by the German troops. 11 Oct.

General Von der Tann, having thus fulfilled his task, was ordered to hold Orleans with the I. Bavarian Corps, and keep a careful watch with his cavalry on the growing strength of the enemy at Tours and Bourges.* The 22nd Division and 4th Cavalry Division were despatched by a westerly route back to the army of investment, but did not proceed further than Chartres, on account of the determined opposition which was offered to them at Chateaudun by some Franc-Tireurs and Gardes Mobiles. 18th Oct.

While the troops of the III. Army had thus cleared the country to the south and southward of the capital, the Meuse Army had been equally successful in a series of petty actions in the north. The French troops opposed to it consisted of small bodies of the National Guard, who were driven back without difficulty to their bases of operations at Amiens and Rouen. On the south-eastern side, near Nogent, several skirmishes of small importance also took place. The positions occupied by the German troops were unaltered during the latter portion of the month, and the territory occupied by the blockading army extended to October.
the Loire on the south, the Eure on the west, and as far as Mondidier on the north.

In the eastern theatre of war, the capture of Strassburg had left the greater part of its besieging force free for further operations. The 27th Sept.
Guard Landwehr Division was sent to Paris, and a XIV. Corps formed and placed under command of General von Werder, for the purpose of checking hostile enterprises from Belfort and its neighbourhood, and in order to clear a new line of communication to the capital by way of Chaumont. The fortresses of Schlestadt and Neu Breisach were at the same time invested by reserve troops. General Werder, after some fighting in the Vosges with detached bodies of the enemy, pushed southwards, and reached Epinal on the 12th October. Finding that a French force was assembling near Besançon, a further advance in three columns was made, and Vesoul reached on the 19th. Two days later a brisk fight took place on the Ognon, the French being thrown back on their main stronghold at Besançon. The defensive position of the enemy being very strong, Werder determined to continue his march westward, dispersing on his way the newly forming levies of Garibaldi. New instructions were, however, received at the end of the month, owing to the expected surrender of Metz. By these the XIV. Corps was detailed for the investment of Belfort, and the general observation of Southern Alsace. In accordance with these fresh orders, Dijon was attacked, and captured after a stubborn resistance on the 31st October, and served 31st Oct.

* To the south and south-west of Orleans.

as a base from which onslaughts were made upon the ubiquitous French levies.

The positions of the contending forces have now been traced up to the end of October, at which period the capitulation of Metz set free the I. and II. German Armies. The active measures taken by the Tours Government were beginning to bring in their fruits. Armies of considerable strength were assembling in the north, south, and east, and from each quarter successive attempts were made to raise the siege of the capital—efforts both independent and unconnected. Communication was, however, maintained between the exterior and interior of the beleagured city, and it will be found that the larger sorties were generally combined with an attempt at relief from the outside.

Attention is first directed to the campaigns on the Loire, which commenced at this period (November), the account of which will be continued up to their close. It must be remembered, however, that although from henceforward the narrative of each separate campaign is kept distinct, they were to a certain extent synchronous; and a careful attention to dates can alone give a fair idea of the difficulties the German forces had to contend with in preventing the raising of the investment of the capital.

Campaign on the Loire.

THE FIRST CAMPAIGN ON THE LOIRE.—Up to the beginning of November the German staff had not been able to acquire accurate information about the newly raised French levies. The Army of the Loire, composed of the *élite* of the existing French forces, was known to be organising somewhere between Bourges and Tours, but its strength and composition were doubtful. An offensive movement towards the capital might soon be looked for, and it was important to discover where the main attack was to be made, so as to concentrate a sufficient force to ward it off. In view of the impending capitulation of Metz, provisional orders had been sent to the II. Army to march as soon as possible with the utmost rapidity towards the Middle Loire, and it was calculated that its leading troops would reach Fontainebleau about the middle of the month. Till it arrived, however, the defence of the country to the south and west of Paris had to be entrusted to the few troops that could be spared from the investing force. No hostile demonstrations were observed during the first days of November, and the troops protecting the investment remained in watchful repose.

Two French corps (15th and 16th), under the command of General de Paladines, were in the meantime assembling to the south and south-west of Orleans, with the intention of making a combined attack on that city, and advancing from thence to second a pre-arranged sortie in force from Paris. The movement was executed with lamentable slowness at the beginning of the month. The main body (about 60,000 strong) moved up the right bank of the Loire from Mer and Marchenoir, while two smaller columns were directed from Salbris* and Gien.

On the afternoon of the 8th of November, General Von der Tann (who was commanding at Orleans) became acquainted with the

* 33 miles south of Orleans.

threatening advance of the main French body. He accordingly moved out his troops to a defensive position at Coulmiers, and telegraphed for assistance to the 22nd Division at Chartres. Attacked on the 9th by very superior forces, he was compelled to retreat with heavy loss towards Paris, finally effecting a junction with the 22nd Division at Toury on the 10th. The French do not on this occasion seem to have taken advantage of their undoubted superiority. By a little better management, an extra 30,000 men might easily have been brought on the field, and the retreat of Von der Tann's troops been seriously imperilled. The German advance to Coulmiers, on the other hand, was undoubtedly judicious, and rendered retirement more easy. Battle of Coulmiers, 9th Nov.

General de Paladines did not follow up his success, but drew his troops together round Orleans, with the intention of converting it into a large entrenched camp, which would serve as a base for further operations. In view of the threatening aspect of affairs, the Germans despatched the 17th Infantry Division from the investing army to Toury, and gave over the command of the whole force to the Duke of Mecklenburgh-Schwerin. Reconnoitring parties sent out towards Orleans met with no resistance, and a general impression existed that an attack from the westward was probably in contemplation. In reality, the French were concentrating their forces round Orleans, having deemed it too hazardous to make an immediate advance, on account of the expected approach of the II. German Army from Metz.

The Duke, however, acting on the information he possessed, pushed the bulk of his force towards Chartres, leaving Toury observed by cavalry. On the 16th his main body was quartered at Chartres, Auneau, and Rambonillet. The II. Army, meanwhile, had started from Metz in three columns, and reached the general line of Troyes-Chaumont on the 10th. On account of the threatening position of the French at Orleans, the march westward was accelerated—the IX. Corps, which was leading, reaching Fontainebleau on the 14th, and gaining a position which enabled it directly to influence the operations for covering the blockade. The advance of the army passed the Yonne on the 15th, thus relieving the Duke of Mecklenburgh of the duty of covering the Orleans-Paris road, and enabling him to undertake the exclusive protection of the western quarter.

The plan of the German leaders was at this period simple. The II. Army had to push forward with its advance troops, and hold defensively the main southern approaches to Paris until its main body had come up. The direction in which any offensive movement could then be made, depended on the situation of the Loire Army—a matter of doubt which the powerful armed reconnaissance of the Duke of Mecklenburgh to the westward would soon clear up. The Grand Duke, on the other hand, had to push forward to the west and south-west, and endeavour to ascertain the character of the resistance in those quarters.

Sharp skirmishes at Dreux, Maintenon, and Chateauneuf soon made it evident that the troops in the western quarter consisted of new levies belonging to a so-called Army of Brittany, some two divisions strong, which was operating from Nogent-le-Rotrou. On the 20th an advance 20th Nov.

was made towards this town, but the French evaded the blow by falling back on Le Mans; thus confirming the already entertained opinion of the German Staff that no part of the Army of the Loire was to be found in the westward. It appeared now certain that the main French army was in the vicinity of Orleans. A telegram was accordingly sent to the Grand Duke to pursue towards Le Mans with cavalry, and convey the bulk of his force without delay to the assistance of the II. Army. To ensure unity of action, the entire German force was placed under the command of Prince Frederick Charles. On the 28th the Duke's troops reached the neighbourhood of Bonneval and Chateaudun.

The II. Army, in the meantime, had arrived on the 20th in the neighbourhood of the following places:—IX. Corps Angerville, III. Corps Pithiviers, X. Corps Montargis, with two cavalry divisions covering the front.*

The IX. and III. Corps advanced southward towards Orleans, the X. Corps closed in towards the centre, and on the 24th of November the German forces occupied an arc extending through Toury and Pithiviers to Beaune-la-Rolande. On this day strong reconnaissances made it apparent that the front line of the French position stretched from Chevilly, by Neuville and Chilleurs, along the edge of the wood to Bellegarde. The outposts of the two armies were thus within a few thousand paces of each other, but the country was so intricate that but little could be seen of the French formations. The Germans were disposed along a line nearly 28 miles in extent, with indifferent lateral communication. The French were far superior in numbers, and could unseen have massed the greater bulk of their force at any one point. On the other hand, owing to the continued wet weather and the heavy nature of the soil, a general advance at this period would necessarily be confined more or less to the roads. If the French did not attack, it would become necessary to storm their lines—a work of great difficulty in a country so close, and well adapted for defence. As the duty of the II. Army was primarily to cover the blockade, their plan at this stage was to act on the defensive if attacked, and if not, to remain in a state of quiescence till joined by the forces of the Grand Duke.

November. The 26th and 27th were passed in trifling outpost engagements, but the threatening attitude of the French right induced the Prince to move his whole force a little to his left, sending at the same time

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* *Strength on 21st November.*

Grand Duke of Mecklenburgh-Schwerin's Command:—	II. Army (under Prince Frederick Charles):—
17th and 22nd Infantry Divisions, I. Bavarian Corps, 4th and 6th Cavalry Divisions.	III., IX., and X., Corps. 1st and 2nd Cavalry Divisions.
36,312 infantry, 9,190 cavalry, 208 guns.	49,607 infantry, 10,176 cavalry, 275 guns.

Forming a total (exclusive of officers, staff, and non-combatants) of 86,000 infantry, 19,400 cavalry, and 484 guns.

instructions to the Grand Duke to close in at once to Toury. While the two armies are thus in close contact, it will be well to view the aspect of affairs from the French side.

After the defeat of Von der Tann at Coulmiers (9th November) the Government was anxious that an advance on Paris should be at once made; but its views were opposed by General de Paladines, on the ground that his troops were neither sufficiently numerous nor well organised to undertake such a movement. The middle of November passed in throwing up a double line of redoubts north of Orleans, and fortifying the line of the edge of the forest by a series of advance posts.

The views of the military and civil authorities were at this stage always clashing. The latter placed too great a value on the fighting powers of the newly-formed levies, while the former attached perhaps too little importance to the advantage of immediate movement. The arrival of the II. German Army on the scene on the 20th rendered an advance for the moment inadvisable. Three new corps were now brought forward—the 18th from the eastern provinces, the 17th and 20th from the western—and gradually moved towards the main body. At the end of the month five French corps (the 15th, 16th, 17th, 18th, and 20th), amounting to about 170,000 men, were bivouacked along a very extended line stretching from the Marchenoir Forest to Montargis.

Battle of Beaune. 28th Nov.

In obedience to orders received direct from the Minister of War, an attack was made on the German X. Corps by the French right. The German troops at Beaune-la-Rolande, though inferior in numbers, held their ground with much pertinacity, and the French corps engaged (18th and 20th) were obliged to fall back on Bellegarde. It was undoubtedly the wish of the French General to maintain a defensive policy until his troops were thoroughly organised, but unfortunately the defective communication with Paris disarranged his plans. Owing to the miscarriage of a balloon, and a misleading telegraphic message, it was thought on the 30th that a sortie with some success had been attempted from the capital, and that it was necessary that an immediate advance should be made to second it.

Second battle of Orleans.

A forward movement was accordingly at once ordered for the 1st December. The original plan for attack was to advance from both flanks simultaneously, and assault both in front and flank the German centre at Pithiviers. From various causes this scheme was not carried out, and an advance was made from the French left only by the 15th, 16th, and 17th Corps, the 18th and 20th Corps on the right remaining immoveable. The French movement met with varying success on the 1st and 2nd December, being opposed obstinately by the troops of the Duke of Mecklenburgh, which had taken up a position across the Orleans-Paris road.

On the 3rd December, Prince Frederick Charles retook the initiative, and observing the French right with cavalry only, made a concentric attack on the centre of their position. Owing to the extension of the French line, the success of this movement resulted in cutting in two the French army. The 16th and 17th Corps retired down the right bank of the Loire, the 18th and 20th retreated in disorder towards Gien, while the 15th alone stood the brunt of the attack of the

succeeding day, on the evening of which Orleans was again occupied by the invaders. On the 6th, the Government of Tours deprived de Paladines of his command, giving over the 15th, 18th, and 20th Corps to the charge of Bourbaki, and detailing Chanzy for the direction of the troops which had retired westward. To these (16th and 17th Corps) were added the newly formed 19th and 21st Corps, the whole bearing the denomination a few days later of the 2nd Army of the Loire.

The disasters which fell upon the French arms in this campaign seem to have resulted principally from the want of accord between the civil and military authorities—that fatal system of dual government so dear to theory and so fatal in practice. It was unfortunate that an advance had to be so hurriedly made without sufficient time being given for proper preparation, but even as it happened the movement does not seem to have been carried out with sufficient energy. To arrive at Paris it was necessary not merely to force a way through the German lines, but to inflict a severe and crushing defeat. The semi-organised French levies could scarcely hope to advance with powerful regular forces on their flanks, and to gain a decided success every available man should have been pushed to the front. As it was, in the battle of Orleans, the 18th and 20th Corps did nothing, and the 17th were only partially engaged. Again, after the doubtful successes of the 2nd December, it is difficult to understand why these corps were not drawn in to Orleans. To carefully fortify a strong position and not utilize it, requires explanation. On the 3rd it was undoubtedly too late; the French army was effectually cut in two, and an endeavour to re-unite could only lead to disaster. The strategy on the German side has been much praised, but it is difficult to say why. Prince Frederick Charles moved his troops to the threatened points when attacked, and when attacking massed his forces for the effort; and his ably carried out plans, though sound, were not especially brilliant.

Second campaign of the Loire.

THE 2ND CAMPAIGN OF THE LOIRE.—After the capture of Orleans the German forces were assembled in the vicinity of the city, and their cavalry pushed forward in pursuit of the retreating columns of the enemy. The French troops had retired on divergent lines; the 15th Corps—which had formed the centre of the army—falling back on Salbris, the 18th and 20th on Gien, and the 16th and 17th towards Beaugency. In order to find out where the next stand of the enemy would be made, Prince Frederick Charles sent the Duke of Mecklenburgh with a powerful force down the Loire, following Bourbaki towards Gien with the III. Corps. The X. and half the IX. Corps remained as a reserve at Orleans. It soon became evident that the right wing of the French army was thoroughly disorganised, and that all efforts would have to be directed against the left wing, which had retired to the westward, under the command of General Chanzy.

On the 7th December the French occupied a strong position extending from the Forest of Marchenoir on the left to the Loire on the right. Map 8. The 16th and 17th Corps had been reinforced by the newly-formed 21st Corps and a portion of the 19th, and numbered more than

100,000 men. The Duke of Mecklenburgh advanced westward on the same date in four columns—the 1st Bavarian Corps and the 17th and 22nd Divisions on the right bank of the river, and the Hessian Division on the left. The bridges across the Loire as far as Beaugency had been destroyed, and pontoons could not be thrown across on account of floating ice.

Battle of Beaugency, 7th, 8th, 9th, and 10th Dec.

A brisk outpost engagement took place on the evening of the 7th, and the German commander, concentrating his troops, attacked the French line near Cravant and Beaumont the next day. But little success was gained, except on the French right, where Beaugency was captured. It became evident that the French were numerically much superior, and requests were accordingly sent to the remainder of the II. Army for assistance. The X. Corps proceeded at once from Orleans towards Beaugency, the IX. Corps reinforced its Hessian Division on the left bank of the river, and the III. Corps, giving up the pursuit eastward, retired on Orleans. On the 9th and 10th a severe struggle was maintained with varying success against the centre of the French line. Counter attacks from the Marchenoir Forest were driven back, and generally speaking the defensive attitude on both sides was successfully maintained, but attacks failed. During the latter days of the battle the numbers on both sides were nearly equal, but the Germans had a decided superiority in cavalry. The French General, aware that Bourbaki was unable to come to his assistance, and fearing the turning of his right flank, gave orders on the 11th for a retreat on Freteval and Vendôme. No opposition was offered to this movement, the German troops being too exhausted by their recent exertions to pursue. The line of the Loir was reached on the 13th, and a defensive position taken up on the right bank, extending between the two above-mentioned towns. By his retreat westward, General Chanzy renounced all chance of a junction with Bourbaki, and left open the direct road to Tours, which had to be abandoned as a seat of Government.

But little was known at the German head-quarters at this period about what was going on to the south of Gien, and great caution was essential in the event of an advance towards Paris being meditated by Bourbaki. It would not be safe to move too far westward, as it would leave the direct road to the capital open. Orleans was accordingly looked upon as the centre from which all offensive operations had to be conducted, and to which the troops should in every case return.

In the belief that Chanzy meant to make a stand behind the Loir, a general advance towards Vendôme was ordered, the I. Bavarian Corps being sent back to Orleans, and Gien held by a strong detachment. The Grand Duke, on the right of the line, came into contact with the French outposts at Freteval on the 13th and 14th of December; but owing to the wet weather and bad roads, the remainder of the army only reached Coulommiers on the 16th.

On the same afternoon, General Chanzy, having little confidence in the shattered *morale* of his troops, determined again to retreat, and eventually reached Le Mans on the 19th with some loss.

All hope of a decisive battle was now lost; and, on the other hand,

intelligence arrived that the detachment at Gien had been driven in by very superior forces. General Werder also reported from the eastern quarter that the troops in front of him were moving westward. As a consequence of the threatening aspect of affairs, a retreat towards Orleans was determined upon, and General Zastrow with the VII. Corps ordered from Chatillon to Auxerre, to support the movement. The III. and IX. Corps were marched at once towards the city, and one division of the X. Corps told off to the pursuit of Chanzy, while the other received instructions to advance on Tours, and cut all the lines of railway communication. The Duke of Mecklenburgh was, in conjunction with the 5th Cavalry Division (from Paris), to clear the country to the north-west, and then go into cantonments at Chartres. The I. Bavarian Corps was sent back to the III. Army at Paris.

The German forces, towards the end of the month, were enabled to enjoy for a few days a well-earned repose at Orleans and Chartres, strong detachments being left at Gien, Vendôme, and Blois, and the country scoured in all directions by cavalry. The instructions received from head-quarters laid down very clearly the course to be pursued. All strength was to be concentrated on a few main points *from which* moveable columns would be sent to clear the country of Franc-Tireurs, and *in which* the troops were to remain till the enemy's levies became organised armies. A short rapid attack was then to be made with all available forces, taking care that the pursuit was not carried too far from the starting point. Following out these views, Prince Frederick Charles remained quiescent till the commencement of January, when definite information came in that the troops of Bourbaki had moved eastward. Reports also arrived from Vendôme stating that strong French detachments were pushing forwards towards the Loir from Le Mans. Telegraphic instructions were sent in consequence from head-quarters that an advance was to be at once made against Chanzy, and that the movements of Bourbaki having taken him out of the zone of operations of the II. Army, might be for the moment neglected.

Campaign of Le Mans.

Map 9.

CAMPAIGN OF LE MANS.—On the 4th January the German forces advanced towards the line of the Loir, which was reached on the 6th. A concentric march on Le Mans in three columns was then ordered. The Duke of Mecklenburgh on the right was directed to push the XIII. Corps* through Illiers to La Ferté Bernard, and gain the main road through the valley of the Huisne. The III. Corps, followed by half the IX., took the central route of Vendôme-Calais, while the X. marched by Montoire-Chartres-Grand Lucé. The front and flank of the army† were covered by four cavalry divisions. In order to secure the blockade to the south while this movement was being carried out, the Hessian Division of the IX. Corps were left at Orleans, strong detachments placed at Gien and Blois, and the II. Corps ordered from the investing army to Montargis. Resistance was offered to each

* The 17th and 22nd Divisions were given this title.

† 57,800 infantry, 15,500 cavalry, 318 guns.

column of advance on the 6th and 7th January, and it was only after some hard fighting that the line of Le Thiel, Authon, and the Braye river was attained. The weather became now very bad, and the severe frost of the 8th was succeeded by a heavy fall of snow, making the roads very slippery and adding much to the difficulty of the march. On the 9th the central column succeeded in pushing as far as the line of the Narrain, but on the two flanks the resistance met with prevented their getting further than Connerré and Brives. On the 10th the forward movement of the Germans was continued, and resulted in driving back the right and centre of the French to their main fortified position in front of Le Mans. On their left, however, the passage of the 17th Division to the right bank of the river was successfully opposed, and the ground held as far in advance as Montfort. The French position on the 11th extended from the Le Mans and Tours road on the right to Monfort and Lambron on the left. It was held by the 16th, 17th, and 21st Corps, the extreme right being entrusted to some Mobiles from Brittany. It was evident on both sides that a decisive battle was imminent. Prince Frederick Charles determined on the 12th to outflank the enemy by making a converging attack, and transferred the whole of the XIII. Corps to the right bank of the Huisne. During the consequent movement of troops, a stubborn fight took place along the whole line, and ground was gradually gained on the French left and centre. On their right, the levies from Brittany gave way at nightfall in panic when attacked by a small portion of the X. Corps (who were advancing up the Tours-Le Mans road). As a result, the position was virtually turned, and orders for retreat at once reluctantly given. Favoured by the darkness of the night and a heavy fog the next morning, the main portion of the French forces retired unobserved on the road to Alençon. The direction of the retreat was eventually altered to the westward, and a position taken up at Laval behind the Mayenne, after some severe rear-guard fighting.

January.

Battle of Le Mans.

The German III. and X. Corps occupied Le Mans, the division of the IX. was sent back to Orleans, and the Duke of Mecklenburgh directed to proceed at once northward towards Rouen. But little further took place on this theatre of war, as the operations of Chanzy's troops were put a stop to by the armistice at the end of January.

The Loire army appears in this campaign to have needlessly sacrificed both the lives and the *morale* of a large proportion of the troops. The columns which disputed the German advance from the Loir to Le Mans were too strong to act simply as rear-guards and too weak to act independently as corps of operation. When forced back on their defensive position their *morale* was much shaken, and affected the fighting powers of the remainder of the force. It was undoubtedly dangerous to leave the right of the line to an unsupported division of raw levies, though this apparently arose more from misadventure than calculation. On the German side, it may be noticed that the detachment of the Duke of Mecklenburgh to the right bank of the Huisne laid him open to be beaten in detail. The fighting power of the Loire army seems to have been unduly undervalued, and under more fortunate circumstances the issue of the engagement might have been very different. It is

impossible to avoid admiring the way in which General Chanzy worked his ill-organised levies, and his retreats are examples of what may be effected under most difficult circumstances with the most indifferent material.

After the armistice, a line of demarcation was fixed between the two opposing armies, and the war in the western quarter virtually ended.

The sequence of events in the eastern quarter must now be referred to, and the decisive campaign of Manteuffel be described.

Campaign in the east.

CAMPAIGN IN THE EAST.—The German forces under General Werder's command in November consisted of the XIV. Corps and the 1st and 4th Reserve Divisions. Their duties were to besiege Belfort, disperse all strong bodies of the enemy in Southern Alsace, and secure the left flank of the main Etappen lines to the capital. On the French side, there were a few regulars at Besançon (who moved by rail westward in the middle of the month), the corps of Garibaldi, west of Dijon, and numerous bands of Franc-Tireurs. In the middle of the month the bulk of the German forces were moved to Dijon, and at its close were enabled to defeat an attempt of Garibaldi to retake the city. The extent of country to be watched by the German General was very large, and a welcome reinforcement, consisting of more than half the VII. Corps, was sent to his assistance from Metz. This force, under the command of General Zastrow, reached the line of Joinville-Chaumont on the 9th December, and was specially charged with the protection of the lines of rail to the westward. As soon as the news reached head-quarters of the division of the French army at Orleans,* the VII. Corps was ordered more to the westward to Auxerre, and General Werder had to detach powerful brigades to invest Langres and watch the railway lines towards Nuits and Chatillon. His main force was, however, in the middle of December, still at Dijon.

Reconnoitring parties sent out on the 16th reported the presence of strong bodies of the enemy, about 12,000 in number, at Nuits.†

An advance was made against these troops (a division of General Cremer's) on the 18th, and they were driven back towards Chagny, after a stubborn fight. Alarming reports came in at this period of the gradual transfer by rail to the eastward of large bodies of the enemy. There were unmistakeable indications of the presence of regular French troops at Besançon and along the line of the Doubs. The object of the French movements was still veiled in obscurity, and it was doubtful whether an advance was about to be made to relieve Belfort or to cut the German lines of supply. To meet either case, the troops of Werder were at the end of the month drawn together at Vesoul, and the VII. Corps ordered back from Auxerre towards Chatillon.

18th Dec.

Reverting for a moment to the Orleans theatre of war, it will be remembered that on the 4th of December the French army under

* 4th December.

† South of Dijon. There are three or four villages of this name, which must not be confounded together.

de Paladines was effectually cut in two. The left wing, as has been related, formed the second army of the Loire under Chanzy; while the remaining three corps gradually converged on Bourges, and were detailed for operations to the eastward. The plan of the French Government was to push these troops towards Dijon, amalgamate with the forces of Garibaldi and Cremer, and raise the siege of Belfort. The ulterior course of operations would depend on circumstances, but an idea was entertained of making a subsequent attack on the German main lines of supply. The movement eastward of the new French army of Bourbaki commenced on the 20th of the month. The 15th Corps was at first left at Vierzon to cover the movement, but a few days later despatched by rail to Besançon. The progress of the troops was slow in the extreme, owing to the maladministration of the railway lines; but after great hardships from the excessive cold weather, they eventually, at the close of the year, were assembled in the neighbourhood of Dole, Dampierre, and Besançon. The force under Bourbaki's command consisted of the 15th, 18th, 20th, and 24th* Corps, and the divisions of Cremer and Garibaldi, forming a total of about 150,000 men with 400 guns. On the 2nd January an advance was made in three main columns up the valley of the Ognon towards Vesoul and Villersexel, where General Werder was expected to make a stand. Cremer's force was detailed to carry out a flanking movement through Gray, while to Garibaldi was entrusted the task of watching the defiles of the Côte d'Or and covering the left flank of the advance.

The appearance of the head of Bourbaki's columns at Villersexel on the 8th at once enlightened General Werder as to the object of this movement. He determined accordingly to make a flank march to a defensive position on the Lisaine, which effectually covered Belfort. To cover the movement and check the French advance, an attack was made on Villersexel on the 9th with about 12,000 men.

Action of Villersexel.

The Germans succeeded in gaining possession of the town after a prolonged fight, but evacuated it during the night, and fell back towards Héricourt. Owing to the check sustained by this attack and the bitterly cold weather, the progress of the French army was very slow, and it was not till the 15th of January the opposing forces came into contact.

January.

The main position taken up by General Werder extended from Frahier, through Héricourt, to Montbéliard, on the left bank of the Lisaine, and was about 10 miles in extent. A few troops were also stationed on the left flank towards Delle; but the ground in this quarter was swampy and impassable, except at a few points.

The Lisaine stream was fordable, but the nature of the ground limited the points of attack, and the heights on the eastern bank afforded admirable positions for artillery. Every arrangement was made for a defensive battle—earthworks were extensively constructed, siege guns detached from the force investing Belfort, and strong advanced posts held on the right bank of the stream. The position of the Germans, on account of their great inferiority in numbers, was very critical. News,

* This newly formed Corps (24th) was raised at Lyons, and Cremer's division nominally belonged to it.

however, arrived that the II. Corps had been ordered from Paris, and that, combined with the whole of the VII. Corps, had arrived on the line Nuits-Chatillon on the 12th of the month. It was apparent that, on account of the distance to be traversed, no immediate assistance was available; but if the crisis could only be delayed for a few days, the pressure of these new reinforcements on the French rear would be felt. The great importance of strongly holding his ground at all risks was most firmly impressed upon General Werder by the Head-Quarter Staff.

Battle of Héricourt, 15th Jan.

On the morning of the 15th, the French advanced to the attack in three main bodies against Montbéliard, Héricourt, and Chagny. The right column (15th Corps) succeeded in establishing itself in the town of Montbéliard, but the Germans held the strong castle. On the centre and left the advanced posts were driven in, with the exception of Chenebier. Why Cremer's Division, which was on the extreme left, was not sent along the main route towards Frahier on this day seems difficult to understand; as also the march of the 18th Corps, which might have availed itself of a good road through Lure, instead of using nearly impassable footpaths.

16th Jan.

After a night of misery from the excessive cold, the attack was renewed on the 16th along the whole line. The advanced post of Chenebier was taken, but the main German positions remained intact. Early on the 17th Chenebier was again lost, but afterwards retaken. Fighting without much spirit was carried on during the day with no marked results, and in the evening Bourbaki, despairing of carrying out his plans, ordered a retreat. It appears tolerably certain that if he had made his attack more vigorously on the third day, or renewed it on a fourth, the German position would have been carried. The attack on the right flank was never seriously pushed, and the fortress of Belfort might well have made a vigorous sortie with half its garrison at an opportune moment.

The plan of the French Government for the relief of Belfort had thus entirely failed. The idea of crushing Werder, raising the siege, and then advancing in force against the German communication, was doubtless seductive, but it entailed a long march through a sterile and mountainous country in close proximity to a neutral frontier. Belfort was in no immediate need of assistance, and its relief would in itself in no way influence the lot of the capital.

The main object of the Government was to raise the siege of Paris, and to effect that in the most easy way the lines of communication with Germany had to be cut. It would have been far better to have advanced at once northward, and have worked for the main object of the Government scheme, in lieu of wasting time in the comparatively unimportant relief of Belfort. Curiously enough, the Germans' communications were at this time especially vulnerable. The entire supplies of the great mass of their forces on the Loire, at Paris, and in the north, were dependent on the existence of the single line of rail from Frouard to Blesme—the cutting of which, even for a couple of days, would enforce the raising of the blockade of Paris. From Dijon to Blesme was but little over 100 miles, and if commenced in time there was absolutely only Etappen troops to bar the march.

The roads were good, the left flank could be easily secured by holding the defiles of the Côte d'Or, Werder might be observed by a detached force, and Langres would serve as a *point d'appui* at which stores might be collected. By starting from Dijon on the 1st January, Blesme might have been reached on the 11th or 12th, and the entire aspect of the war operations changed. That such a movement entailed some after risk is of course obvious; but still it was quite possible, and afforded a most brilliant opening of which unfortunately no advantage was taken.

Retreat of Bourbaki.

On the 17th the French retreated in disorder along the valleys of the Ognon and Doubs, and eventually reached Besançon on the 22nd, being followed up by the troops of Werder. Here it became evident that fresh forces were threatening the intended line of retreat, and endeavouring to cut off the French corps from their natural base of Lyons. These newly arriving troops were the II. and VII. Corps, under General Manteuffel, who, as has been mentioned, were at Chatillon and Nuits on the 12th January. From these points it would have been advantageous, both on account of the good roads, and the presence on the flank of the hostile fort of Langres, to advance directly on Dijon and overwhelm the Garibaldians there situated. The critical position of General Werder, however, in front of Belfort, induced Manteuffel to march directly to his assistance, through the difficult defiles of the Côte d'Or. By following this course the pressure on the French flank would be sooner felt, and in the event of the by no means impossible contingency of the XIV. Corps being compelled to retreat, the rear of the French pursuing army could be attacked. Orders were accordingly issued to cross the Côte d'Or in three main columns—an operation of difficulty on account of the severe frost, and of danger from the total absence of lateral communications. On the 17th of January the defiles were passed, in the face of a trifling resistance, and the main road from Langres to Dijon reached. On the 18th the march eastward was resumed, the left flank being well in advance, and on the following day, in consequence of the news of the successful issue of Héricourt, a wheel to the right was ordered, and the line of the Saône reached at Dampierre and Gray. By previous arrangement, the base of supply was shifted from Chatillon to Epinal.

Advance of Manteuffel

Bourbaki's position was now critical. While Werder was following upon his rear, the advance of Manteuffel threatened him on the flank, and in the only path of safety lay the neutral Swiss frontier. To the corps of Garibaldi had been entrusted the duty of covering the exposed flank, but the troops at Dijon were not sufficiently strong for that purpose, and the nature of his task does not appear to have been understood by the Italian General.

Justly appreciating the strategic situation, General Manteuffel determined to advance at once southward, and, masking the force of Garibaldi, to effectually cut off the retreat of the main French army. The fulfilment of such a plan taxed to the utmost the efficiency of his troops, and entailed the great risk of losing his lines of communication. The only way to obtain a great result was to pin Bourbaki against the Swiss frontier; and to effect this, the II. and VII. Army Corps would have to advance rapidly, and act for the time independently of the XIV., which was following up the retreat. The manœuvre was a remarkably

venturesome one, but still, considering the nature of the French levies, was probably justifiable. On the 21st the line of the Ognon was reached at Pesmes, Marnay, and Pin, the advanced guard of the II. Corps seizing Dôle, 14 miles to the front. On the 23rd inst., the main route of Besançon-Lons-le-Saulnier was occupied, and the direct communication of Bourbaki with Lyons cut off. The VII. Corps was thus established in a strong position on both banks of the Doubs, a little to the eastward of Dampierre. The II. Corps reached the main road further south at Villers-Farly.

To cover the flank of his advance from the troops of Garibaldi, Manteuffel had ordered Kettler's brigade (near Montbard), which had been left behind at Nuits in the first instance, to attack Dijon. These troops, though unable to force back Garibaldi, maintained their positions close to the town on the 21st, 22nd, and 23rd, and thus effectually fulfilled the task of holding the enemy fast. General Werder had on this date reached the line of Monbouzon-Clerval, and the touch of the French army had been thus everywhere gained. The essential point was now to join the two independently acting German bodies, and by pushing further to the south, seize all the remaining lines of retreat through the Jura. The troops of Manteuffel, by pushing forward strong reconnaissances, found that the French troops were still in the neighbourhood of Besançon. General Werder, on account of the difficult nature of the country between the Doubs and Ognon, and from a fear of Bourbaki's making a direct march on Gray, moved the bulk of his force across the Ognon. This movement was arrested on the 26th by General Manteuffel, and the XIV. Corps directed to advance on Besançon, *viâ* Marnay. The German corps were now in contact, and powerful enough to assume the offensive. On the 28th the advance into the Jura by the VII. and II. Corps was commenced, the observation of Besançon on both banks of the Doubs being confided to Werder.

From reconnaissances made the two previous days, it was known that the French were in retreat; but whether they were at Pontarlier, or had pushed further to the south-west, was doubtful. The VII. Corps was accordingly pushed forward through Deservilliers on Pontarlier, while the II. was ordered to seize Les Planches.

On both these lines of advance resistance was encountered, and many prisoners taken. The French had, in the meantime, retreated from Besançon to Pontarlier, with the intention of gaining the open country through Mouthe-Foncine-St. Laurent—a defile which was on this date barred. All operations were suspended on the 30th, on account of the news of the armistice; but when it became known that it did not apply to the Southern Army, vigorous operations were prescribed for the following day. A converging attack was made on Pontarlier on the 1st February, the town taken, and the debris* of the French army, cut off from all hope of escape, took refuge in the neutral Swiss territory.

In the meantime, the siege of Belfort was being vigorously prosecuted, and some of the outworks taken. By arrangement, however, between

* 85,000 men, with 12,000 horse and 285 guns. The remainder of the forces were either taken prisoners or escaped through the mountains.

the two Governments, hostilities came to an end, and the fortress was formally surrendered to the German troops on the 18th February.

The operations of Manteuffel, under very difficult circumstances, seem to have been most skillfully carried out. The departure of Werder from his views with regard to an immediate concentric advance on Besançon probably prevented the occurrence of another Sedan, but still it led to an equivalent result being obtained with much less loss. The disasters of Bourbaki's retreat may be fairly attributed to other causes than the deficiency of the material he had to deal with. The measures necessary to secure the flank of his advance would, if carried out, have allowed of a safe retreat. Bourbaki considered that it was the duty of Garibaldi to protect his communications; while Garibaldi avers with some justice that he had not enough men for the purpose, nor was his task clearly pointed out to him. These unfortunate misconceptions appear to have arisen chiefly from the constant interferences of the civil with the military authorities, and it is difficult to apportion the blame. Assuming, however, that Garibaldi was only capable of holding Dijon, it would appear that since the fortress of Auxonne was occupied by French troops, the ground to the right of that town—*i.e.*, the country lying between the Doubs and Saône—should naturally have been guarded by Bourbaki. If the 15th Corps had, as originally intended, been left near Auxonne, the retreat would have been comparatively safe. Even as it was, the measures taken to cover the mountain passes were most inefficient, and if they had been held strongly there was nothing to prevent a successful march through the Mouthe-Foncine defile.

The three days' delay at Besançon was most unfortunate, and there seems to have been a misunderstanding as to the amount of the provisions in the place, which were quite sufficient to victual the army for a march through the mountains. The whole key to the matter seems, however, to lie in the want of vigour with which the battle of Héricourt was fought. The weather was certainly adverse, but the one chance of keeping the raw French levies effective was to force a success regardless of expenditure. In spite of the declamations of both sides as to their respective valour, the losses* tell too truly that frost and disease were the most formidable opponents encountered. The curious error by which the French Commander-in-Chief was deceived on the 29th as to the terms of the armistice is difficult to explain; but it is worthy of note that all these accidental delays by which the fates of armies were settled were invariably favourable to the German cause.

Campaign in the North.—After the fall of Metz, General Manteuffel was appointed to the command of the I. Army, which was destined for operations to the north of Paris. The VII. Corps was detailed to garrison Metz† and besiege Thionville and Montmèdy; the 1st Infantry

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* The total loss of Werder's corps from the 10th to the 20th January was 317 killed, 1500 wounded. The French loss probably amounted to 8000 men.

† The 3rd Reserve Division was attached to the VII. Corps. Its Landwehr infantry acted as escort to Germany of the captive army; while the remainder, under General von Senden, relieved the 1st Infantry Division at Mezières on the 21st November.

Division of the I. Corps was advanced toward Mezières, and one brigade of the same corps detached for the siege of La Fère. The 3rd Cavalry Division, in the meantime, pushed westwards towards Rethel, and, disarming the population in the Argonnes, awaited the arrival of the main body. On the 7th November the march of the remainder of the army commenced, and the general line of Compèigne-Noyon on the Oise reached on the 20th without opposition.* The reconnaissances sent out towards Amiens made it clear that a considerable force of the enemy were being concentrated there, and orders were accordingly issued for an advance against them.

On the 25th the I. Corps reached Roye, the VIII. Corps Breteuil and Montdidier, and on the following day it was apparent that the French intended accepting battle at Amiens.

Battle of Amiens, 27th Nov.

The French Army of the North, which now appears upon the scene, was composed chiefly of Mobiles, led by officers who had escaped from Metz and Sedan, and numbered from 25,000 to 30,000 men. To protect Amiens, a position had been taken up to the south-east of it, with the left flank resting on the river Somme.

The Germans attacked vigorously both flanks of the position, and in spite of most obstinate resistance obtained success at all points. The French forces retired northward towards Arras in good order, leaving a small garrison in the citadel of Amiens, which was obliged to surrender two days later. Possession of the fortress of La Fère was also gained at this date, thus giving too strong *points d'appui* on the Somme to facilitate a further advance.

The French troops dispersed among the several northern depôts, for the purposes of reorganisation, while Manteuffel marched westward with the bulk of his forces against the corps of General Briand—at this time at Rouen. After some isolated fighting, this city was entered on the 5th December, and strong reconnoitring parties sent out in all directions. One division of the VIII. Corps was sent towards Havre, but the town was too strongly garrisoned and fortified to admit of attack. Dieppe was at the same time captured without resistance, and the country westward cleared as far as the Rille.

December.

Alarming reports came in at this period from the eastward to the effect that French troops had captured Ham on the 9th of the month, and threatened La Fère a few days later. To prevent a further advance towards Paris, orders were issued for the main body of the I. German Army to concentrate at Beauvais, and assistance telegraphed for, both to the Meuse Army and the force investing Mezières.

It soon became evident that the French forces (now under the command of General Faidherbe), were advancing westward towards Amiens. The troops of Manteuffel were in consequence concentrated to the south of the town, and the detachment of the Army of the Meuse, now deemed superfluous, ordered back to the investing lines.

		Infantry.	Cavalry.	Guns.
* Strength on 21st Nov.	1st Corps	19,148	1084	84
	8th Corps	19,096	1139	90
	3rd Cav. Div.	—	2210	6
	Total	38,244	4433	180

On the 20th of December a reconnoitring force brought back intelligence that the French were strongly established in a defensive position on the left bank of the Hallue, and had no apparent intention of a further advance. Manteuffel determined at once to attack on the 23rd, and endeavour if possible to turn the enemy's right flank.*

Battle on the Hallue.

The French advanced troops were easily pushed back as far as the Hallue stream, and eventually, after obstinate fighting, the villages in the valley captured. All efforts to scale the opposite ridge were, however, unsuccessful, as well as the attempt to turn the right flank. The two armies confronted each other on the 24th without any serious fighting, and in the afternoon the French, unwilling to risk their ill-clad forces to another night's bivouac, drew off in good order towards Arras.

The Germans pushed forward as far as Bapaume, and at the same time invested the small but important fortress of Peronne. Matters had assumed meanwhile a more menacing aspect to the westward. A French force, estimated at from 15,000 to 20,000 men, was advancing from the direction of Havre, on both banks of the Seine, towards Rouen. The German troops were accordingly reinforced by rail, and by taking a vigorous offensive forced them back at the beginning of the new year to their original bases at Honfleur and Havre.

The normal distribution of the I. Army was therefore in January in two principal masses,† at Rouen and on the Somme, the extreme right of the latter force being covered by cavalry‡ detached from the Army of the Meuse. This division of forces was accompanied with but slight danger, on account of the lines of rail connecting Paris, Rouen, and Amiens, by means of which a concentration on any one point could be easily effected.

Battle of Bapaume, 3rd Jan.

The bombardment of Peronne was carried on without result till the 2nd of January, when the covering force north of Bapaume was driven in by the advance of the whole of Faidherbe's troops. The French General was marching southward from Arras in four columns, with the intention of endeavouring to raise the siege of Peronne. On the 3rd the German troops,§ who had concentrated in the immediate vicinity of Bapaume, were vigorously attacked, and after an obstinate resistance compelled to surrender all their advanced posts. Although Bapaume was still held in the evening, a renewal of the action did not look promising to the Germans in the face of the increasing numbers of their enemy, and a

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* Instructions were previously sent to the 12th Cavalry Division (of the Army of the Meuse) to advance towards St. Quentin, and protect the march of the detachment from Mezières before alluded to.

		Infantry.	Cavalry.	Guns.
† I. Corps. 1 Brigade Dragoons.	at Rouen.....	20,000	2,200	84
VIII. Corps. 3rd Reserve Division. 3rd Cavalry Division. Bde. Guard Cavalry. 12th Cav. Division.	on the Somme	21,800	7,200	125

‡ 12th (Saxon) Cavalry Division.

§ 17 battalions, 24 squadrons, 64 guns. The effective strength of these battalions was very low. Faidherbe states that about 20,000 French troops took an effective part in the action, but he had altogether apparently about 40,000 men.

retreat towards Peronne was at once ordered. Contrary to all expectation, the French did not follow up their success, but retired again to their cantonments south of Arras.

On the 10th of January Peronne capitulated, after a severe bombardment, and its capture left the Germans in possession of the entire line of the Somme.* It now became possible to retire the troops to the south of this river, where they could enjoy perfect rest. By pushing forward slight advanced guards, the advance of Faidherbe could always be felt, and concentration to meet his movement be effected with ease behind a strong defensive line.

General Faidherbe, after revictualling his troops, pushed forward and occupied Bapaume on the 11th of January. Pursuing his march southward, he gained Albert without resistance on the 14th, and sent out strong reconnaissances the following day. It at once became evident that the swampy valley of the Somme could never be passed in the presence of the I. German Army, and the only course now left open was to endeavour to gain St. Quentin, and threaten an advance on Paris. Though too weak in numbers to endeavour to raise the investment, such a movement would probably draw considerable German forces together, and assist the "supreme effort" of Paris, of which notice had been received.

The main portion of the French army started accordingly on the 16th for Sailly and the villages in the neighbourhood of Combles.† On the following day the march was directed in several columns on St. Quentin. After a slight engagement on the 18th, the French, constrained by the pressure of the approaching German forces, took up a position to the west and south of St. Quentin. The Germans, in the meanwhile, had rapidly moved their divisions towards the town, and made arrangements for an attack on the 19th. The army was divided into two commands—one force to attack from the south, the other from the west, while cavalry on the outer flanks were to endeavour to cut the French lines of retreat. After seven hours' hard fighting, Faidherbe was driven out of his positions, and retreated in tolerable order with all his field artillery on the routes of Cambrai and Le Cateau.‡

Battle of St. Quentin, 19th Jan.

A pursuit was ordered on the 20th, but led to little result; and after temporally occupying the country from Le Cateau to Bapaume, the mass of the German forces fell back behind the Somme—a position they retained when the armistice was proclaimed.

The campaign in the north of France, on account of the small numbers of the forces engaged in it, has not received the notice it fairly merits. The German commander was completely successful in his object of covering the investment of Paris, and the ability he displayed in employing the lines of rail for the transfer of troops to threatened points is worthy of notice. It may be fairly questioned, however, whether,

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* General Von Goeben succeeded Manteuffel on 9th January, the latter taking command of the South Army.

† Troops to meet this movement were at once ordered by rail from Rouen, a strong division of the I. Corps only being left there.

	Infantry.	Cavalry.	Guns.
‡ German forces in this battle	23,400	6,200	161
French " " "	48,500	500	96

considering the raw levies opposed to him, he was so successful as might have been expected of him. Though the weather was undoubtedly bad and unfavourable to its movement, the German cavalry do not seem to have done their usual share of the work, considering that the French Army of the North had but one mounted regiment. At St. Quentin, again, an absurd attempt was made to surround Faidherbe, which converted what might have been a crushing victory into but a trifling success.

The action of Faidherbe, on the French side, seems most meritorious. With raw ill-clad levies he succeeded in fighting three obstinate battles with the veterans of the I. Army. The troops of General Briand, on the other hand, seem to have displayed little activity, contenting themselves with reconnaissance and small actions, and never venturing on a general engagement. Why the two French masses did not act in unison will always be a matter of curiosity. Although fair reasons might exist for not uniting the French armies, they might surely have manœuvred for combined action. Manteuffel was more than once in a critical state from the advance of Faidherbe, and it may be easily conceived that an additional force of 25,000 men brought against him might have materially altered the aspect of affairs. Without entering into detail, it must be admitted that the action of the French Army of the North was very remarkable, and leads one to the conclusion that the intrinsic defects of a raw soldiery may be in a great measure obviated by a judicious leader. Although Faidherbe did not follow up his successes at the Hallue or Bapaume, it was undoubtedly with good reason. He made the most of the material entrusted to him by not requiring too much from it, and his power of preserving the discipline and efficiency of his troops contrasts favourably with that shown by the less fortunate commanders of the Armies of the East and West.

Siege of Paris.

The siege of Paris by the III. and IV. German Armies, for the raising of which the wars in the provinces had been waged without success, must now again be reverted to. The issue of the action at Le Bourget,* the news of the fall of Metz, and the unsuccessful attempts of M. Thiers to obtain peace, led naturally to much apprehension in the capital, and in the beginning of November a fresh organisation of the military forces was made, and the formation of three distinct armies decreed. The nominal effective of these forces was very large, and presented a great disproportion to their actual value. The troops of the 2nd Army, under General Ducrot, were alone available for field operations, and may be fairly estimated at 105,000 men. Preparations were made to utilise these newly formed forces in a grand sortie to the north-west towards Rouen—a plan which was abandoned, however, as soon as the news arrived of the successful issue of the battle of Coulmiers,† and the recapture of Orleans by de Paladines. To second the efforts of the advancing army of the Loire, it was necessary to effect a *trouée* to the southward. Two courses were practically open to the French com-

* 28th October. (See Part II.)
† First Loire Campaign.

mander—either to act on the left bank of the Seine, under the protection of the forts of Ivry and Montrouge, against a position which was known to be strongly entrenched, or to cross the Marne and advance against the heights of Villiers and Champigny, where the Germans were in less force. By constructing numerous bridges, the difficulty of crossing the river might in the latter case be reduced to a minimum, and the movement of the troops be protected by utilising the plateau of Mont Avron and the peninsula of St. Maur on the two flanks. Orders were accordingly given to carry out the sortie on the 29th of November; the materials for bridges having been collected the previous night at Joinville, Nogent, Brie, and Neuilly, and the plateau of Avron crowned by artillery. Strong false attacks were at the same time to be made against the German positions in other quarters, especially towards L'Hay and Chevilly.* The operation appears to have been well planned, and if the extraordinary fatality which seemed to follow the French cause had not intervened, there is but little doubt the 15,000 German troops in this quarter could not have arrested the movement. A rising of the waters of the Marne on the night of the 28th rendered it impossible to anchor the bridges, and the forward movement was delayed for 24 hours, enabling the besiegers to move reinforcements to the threatened quarter. On the 30th, the troops of Ducrot, divided into three corps, crossed the river on ten bridges, their advance being preluded by a heavy cannonade from the plateau of Avron and Fort Nogent. The German outpost line was pushed in, and Champigny and the crest of the Cœuilly plateau held. In the face of the opposition encountered, no further advance was made on the 1st of December, and on the following day the Germans retook the initiative, and attacked with varying success the whole French line. The sortie having now completely failed, the French army withdrew without opposition across the Marne on the 3rd.

Sortie of Ducrot.

It is not difficult to realise what would have been the fate of Ducrot if he had forced the German lines on the 30th of November. The Army of the Loire was at this date unable to defend itself, and could in no wise lend him a helping hand. Although a temporary relief of the investment would undoubtedly have taken place, it would not have affected the fate of the capital, and the French army, in an open country destitute of provisions, must have been speedily surrounded by troops detached from the blockading lines.

The early part of December was spent in re-organising the defeated French troops, and after the reception of a despatch from Gambetta explaining the situation of affairs in the provinces, a fresh attack was ordered against the nort-west quarter. It was not apparently intended to make a sortie, but simply to push back the investing line and break the strict cordon of observation. After some unnecessary delay, the attack took place on the 21st of December between St. Denis and the Marne. General Vinoy, who commanded the right of the advance, pushed back successfully the outpost line, but all efforts directed against Le Bourget on the left failed. A bitter frost on the two following days

Sortie towards LeBourget.

* The corps of Vinoy captured L'Hay before he was informed of the change of the date of the main attack, and suffered severe loss in its retreat.

prevented the renewal of operations, and the troops were withdrawn to Paris. On the 27th, a concentrated fire of artillery was directed by the Germans against the plateau of Avron, which had to be abandoned by the besieged the next day.

At the beginning of the new year the position of affairs was somewhat complex. The efforts of the Parisians to break the blockade had not hitherto been attended with success, but it was undoubted that the number of their effective troops had largely increased, and it was probable that a sortie on a large scale would be shortly attempted. Bourbaki, with about 90,000 men, was at this time near Bourges, in a somewhat disorganised state; Chanzy, at Le Mans, possessed nearly 150,000 men; while Faidherbe had a tolerably disciplined force of 50,000 men in the north. To the eastward, the corps of Garibaldi and Cremer amounted to about 30,000 men; while General Briand's troops at Havre numbered about 15,000. To prevent the concerted action of these diverse bodies, the German forces were thus disposed:—The III. and IV. Army effectually invested Paris; the I. Army, in two main groups at Rouen and Amiens, covered the blockade to the north; the II. Army had its main strength at Orleans, with detachments at Vendôme, Blois, and Gien; the Duke of Mecklenburgh was posted at Chartres, to watch the approaches from Le Mans and the west; while General Werder besieged and covered the investment of Belfort.

The siege of Paris had already been protracted to an unexpected extent, and on account of the difficulties of transport no artillery attack had yet been made on its forts. This state of affairs was, however, altered on the 5th of January, when 96 heavy guns opened fire on the forts of Issy, Vanves, and Montrouge. To the north, east, and south, batteries were quickly formed, and a heavy fire maintained on both forts and houses within range. The actual effect of this bombardment was not at first very conspicuous. Fort Issy was the most damaged, but was still capable of repelling assault; and the killing of a few inoffensive inhabitants in the city only enraged the populace. The provisions, however, were rapidly coming to an end, and a final supreme effort was ordered to be made against the enemy's lines. About 83,000 men were assembled on the 19th January, under cover of Mount Valerien, and advanced against Buzenval, La Bergerie, and Montretout in three main columns. After encountering severe loss in attempting to force the strongly entrenched German positions, a retreat was ordered, and the last hope of the beleaguered city destroyed. Provisions for a few days only now remained, and necessitated the acceptance of an armistice on the 28th January, 1871, which virtually terminated the greatest and most obstinately fought war of modern times.

The last sortie.

[For the convenience of the student, a list of the principal books on the campaign is appended. All the German works of note have been translated into either English or French:—Franco-German War (official account); accounts of Borbstaedt, Blume, Lecompte, Mazade, Vial, Ambert, C.D., Vandevelde, Rustow, Niemann, Farcy; Operations of I. Army (3 vols.), by Wartensleben and Schell; German Artillery, by Hoffbauer; German Engineers, by Goetze; Operations of South Army, by Wartensleben; XIV. Corps, by Lohlein; Opérations de la III. Armée, by Hahnke; Opérations du V. Corps, by Heydekamp; La Première Armée de la Loire, by De Paladines; La Deuxième Armée de la Loire, by Chanzy; L'Invasion dans l'Est, by Cremer; La Guerre en Province, by Freycinet; L'Armée du Rhin, by Bazaine; L'Armée du Nord, by Faidherbe; Journal d'un Officier de l'Armée du Rhin; Trois mois à l'Armée de Metz; La Guerre dans l'Ouest, by Rollin; Siège de Paris, by Ducrot; Do. by Vinoy and Le Duc; Metz Campagne et Negotiations; La Guerre le jour en jour; Etude d'ensemble de la Campagne; Operations of Bavarian Corps.]

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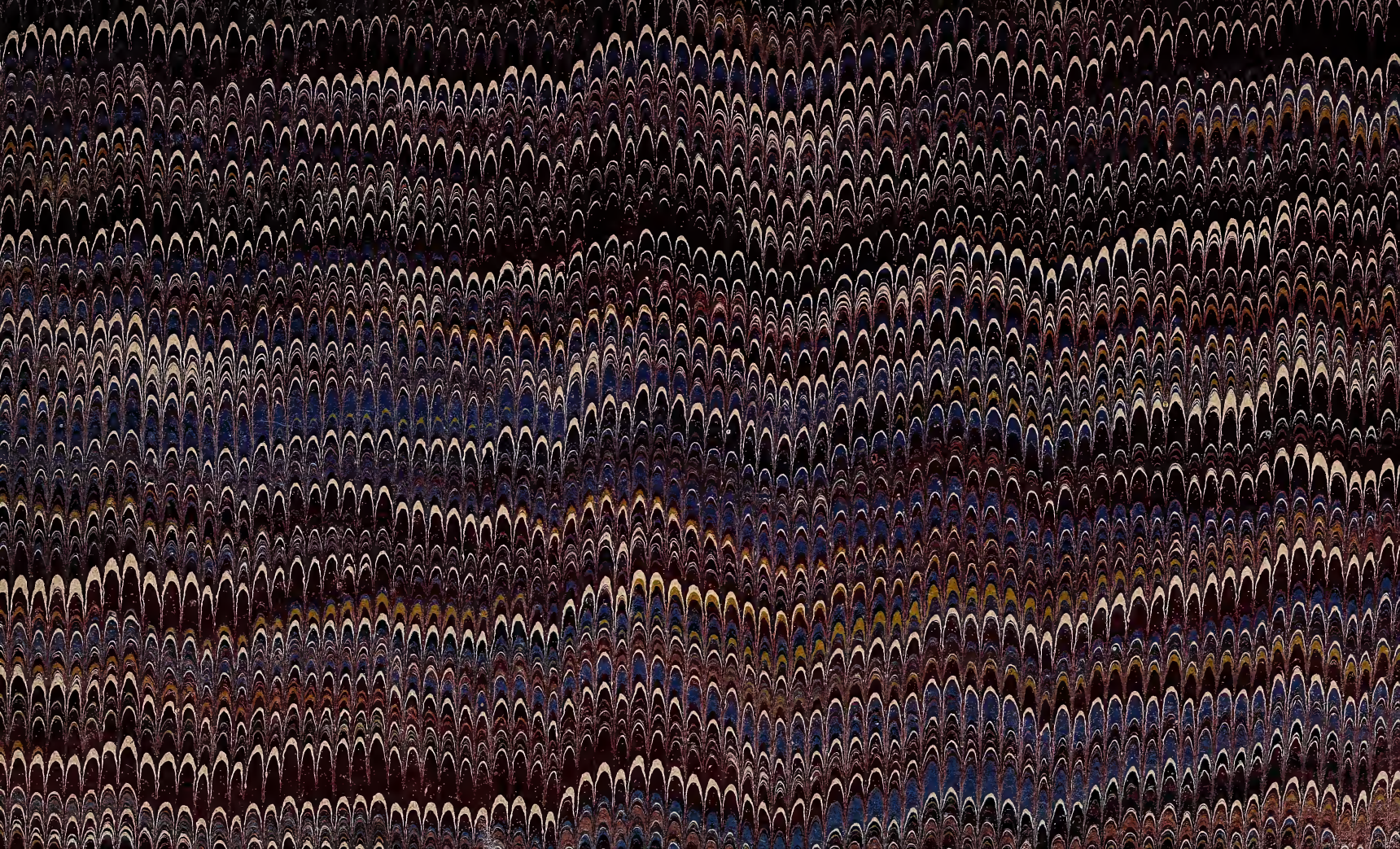

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